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GROUNDWATER CLASSIFICATION

For the
Weldon Spring Site Remedial Action Project
Weldon Spring, Missouri

Prepared by MK-Ferguson Company and Jacobs Engineering Group

APRIL 1990 REV. 0

U.S. Department Of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

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Groundwater Classification

April 1990

Revision 0

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ABSTRACT

The purpose of the Weldon Spring Site Remedial Action Project (WSSRAP) is to study the area including and surrounding an abandoned chemical plant and related waste disposal facilities, with the ultimate goal of identifying and disposing of radiologically and chemically contaminated materials and other hazardous wastes associated with past plant operations. One aspect of this project involves the classification of groundwater in the area based on U.S. Environmental Protection Agency (EPA) strategy and guidelines. After analyzing the physical characteristics of the site, including geology, surface water hydrology, hydrogeology, groundwater movement and quality, springs and seeps, and ecology, the site was divided into three classification review areas (CRAs) reflecting boundaries based on hydrogeologic conditions and following the EPA guidelines. Water use surveys were then conducted and the three CRAs categorized according to the EPA's groundwater protection strategy.

The EPA guidelines were adopted to maintain consistency in its groundwater protection programs. A significant part of the EPA's groundwater protection strategy is to classify groundwater into three categories on the basis of the highest beneficial use to which groundwater presently or potentially can be put. The groundwater at all three established Classification Review Areas at WSSRAP has been determined to be Class II - Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses.

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1 INTRODUCTION

1.1 PURPOSE OF REPORT

The purpose of this report is to classify groundwater resources around the Weldon Spring Site (WSS) in accordance with the U.S. Environmental Protection Agency (EPA) Guidelines for Groundwater Classification under the EPA Groundwater Protection Strategy (EPA, 1986). The draft U.S. Department of Energy (DOE) position paper on Groundwater Protection, Section 3.1, states that one element of DOE groundwater protection strategy is to voluntarily conform to the EPA groundwater protection strategy (DOE, 1988). Therefore, the DOE has classified the groundwater at the Weldon Spring Chemical Plant, Weldon Spring Raffinate Pits, Weldon Spring Vicinity Properties (collectively, the WSCP/WSRP/WSVP) and the Weldon Spring Quarry (WSQ) as outlined in the EPA groundwater protection strategy. Section 4.2.2 of the DOE position paper sets standards for remedial action for each classification unit.

Groundwater Classification Review Areas (CRA) were defined around the raffinate pits, chemical plant, vicinity properties, and the quarry. Physical and cultural aspects of groundwater occurrence and use were evaluated for each CRA, and the groundwater was classified accordingly.

The EPA issued its Groundwater Protection Strategy document in August 1984 to provide a common reference for responsible institutions as they work toward the goal of preserving clean groundwater. As a follow-up to this strategy, the EPA has also provided a guidance document for groundwater classification. This document provides guidance on groundwater protection policy and procedures for identifying the highest beneficial use to which groundwater resources can presently or potentially be put. It defines a groundwater classification system and specifies the procedures and information needed to classify groundwater within that system. The EPA's groundwater classification system separates groundwater resources into hierarchical categories on the basis of their value to society, present and potential use, and vulnerability to contamination. The guidelines are intended to provide a framework for the decisions that the EPA and the states will have to make in implementing programs impacting groundwater resources (U.S. EPA, 1984, 1986).

The guidelines are used by the EPA and the states to make decisions on levels of protection and cleanup under existing regulations, to guide future regulations, and to establish enforcement priorities. The regulations provide the legal basis for the implementation of the guidelines. The EPA groundwater protection strategy is not intended to specify substantive or procedural rights. While the guidelines are not promulgated regulations and are not potential Applicable and/or Relevant and Appropriate Requirements (ARARs) for a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup action, they should be used as appropriate for determining proper CERCLA responses. Maximum Contaminant Levels (MCLs) are generally the relevant and appropriate Federal standards for Class I and II waters (see Section 5). MCLs are neither applicable nor relevant and appropriate for Class III waters. (Cleanup of Class III waters is unlikely although environmental protection or risk from migration may create a cleanup need.) If MCLs are not promulgated under the specific site circumstances, then environmental and public health criteria, advisories, guidance, and proposed standards should be considered.

The following sections discuss data used in this groundwater classification for the Weldon Spring Site Remedial Action Project (WSSRAP) sites, including the geologic and hydrologic characteristics of the water-bearing units, the possibility of groundwater supplying habitat for rare or endangered species, the public and private wells that supply groundwater from within the WSS area, and the availability and economic feasibility of alternative water supplies.

1.2 SITE LOCATION AND DESCRIPTION

The WSCP/WSRP/WSVP and WSQ are located in western St. Charles County, Missouri, approximately 30 miles west of St. Louis on Missouri Highway 94. The WSCP/WSRP/WSVP are approximately 2 miles southwest of the junction of U. S. Highway 40 and State Highway 94 (MK-Ferguson, 1987b). The WSQ is located about 3 miles southwest of the chemical plant and about 4 miles southwest of the city of Weldon Spring in St. Charles County (Figure 1-1).

The 169-acre WSCP consists of 13 major buildings and approximately 30 support structures. Some are chemically and/or radioactively contaminated. The 52-acre WSRP area is contiguous to the WSCP on its western side; it contains four raffinate pits covering approximately 26 acres. These pits contain the residues of uranium and thorium processing from the former uranium feed materials plant (WSUFMP) (MKF, 1987b).

The vicinity properties are areas near the raffinate pits and chemical plant area and the quarry--but outside the current fenced boundaries--that are contaminated as a result of previous activities conducted at the site. Contamination in the vicinity properties is located mainly along ditches, drainageways, roads, and railroads. Some nearby ponds and lakes are also contaminated.

The WSQ is excavated into a ridge top adjacent to the Missouri River floodplain. The two-acre floor of the quarry is

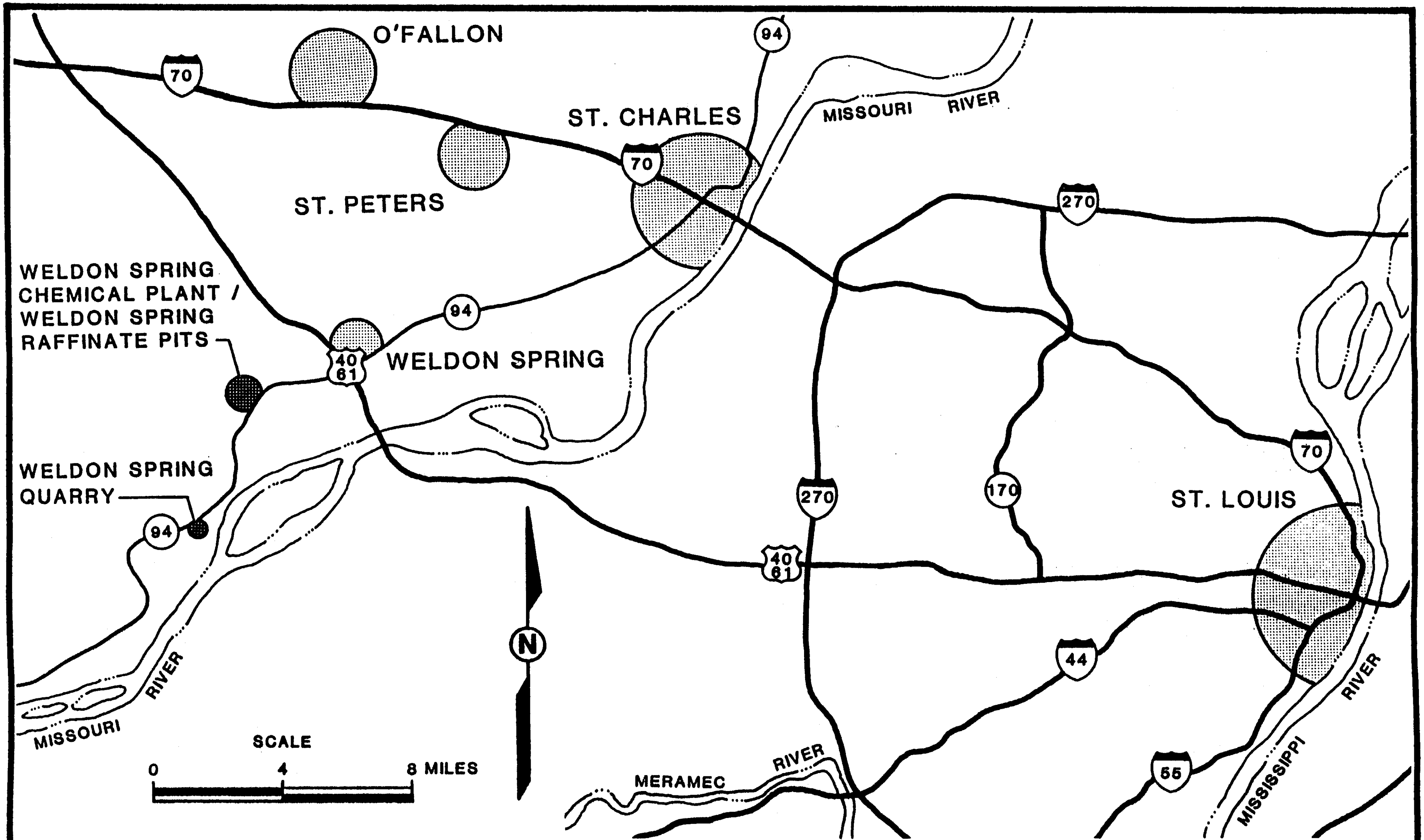


FIGURE 1-1

LOCATION OF THE WELDON SPRING SITE

about 70 feet below the high rim. The deepest portion of the floor is covered by a pond containing approximately 3 million gallons of water and occupying about 0.5 acre. The quarry waste contains nitroaromatic compounds, radiochemically contaminated waste, rubble, and other less well characterized organic and inorganic contaminants.

1.3 SITE HISTORY

The Department of the Army (DA) utilized the Weldon Spring Site and surrounding areas from 1941 to 1944 to produce explosives, including trinitrotoluene (TNT) and dinitrotoluene (DNT). The DA conducted decontamination operations in 1946, razing over 200 buildings and burning approximately 90 tons of nitroaromatics and residues (MKF, 1987a). In 1956, the Army transferred about 205 acres to the U.S. Atomic Energy Commission (AEC) for the construction of a uranium feed materials plant on the DA's previous manufacturing site. From 1957 to 1966, the AEC operated the WSUFMP, which subsequently became the Weldon Spring Chemical Plant. Uranium ore concentrates and some scrap metal were processed at the plant. Products that included uranium metal were then shipped to other sites. Materials containing thorium were also processed on an intermittent basis. Radioactive sludge residues (raffinates) were placed in the raffinate pits.

In 1967, after the AEC had closed it, the DA reacquired the WSCP. In 1971, the DA returned the 52-acre portion of the site containing the raffinate pits to the AEC. As successor to the AEC, the DOE assumed responsibility for the raffinate pits, primarily because of their radioactive contamination. In 1984, the DA repaired several of the buildings at the chemical plant; decontaminated some of the floors, walls, and ceilings; and isolated some contaminated equipment.

Prior to 1942 the WSQ was mined for limestone aggregate used for construction materials in the Weldon Spring Ordnance Works (WSOW). From 1942 to 1969, the DA and the AEC intermittently used the WSQ for the disposal of wastes. From 1942 to 1945 the DA used it as a burn pit for wastes generated by the WSOW. Rubble contaminated with TNT and other nitroaromatic compounds was dumped in the WSQ from 1946 to 1957. In 1958 the AEC assumed custody of the WSQ from the DA. From 1959 to 1969 the AEC disposed of thorium, radium, and uranium residues in the WSQ. Rubble from the uranium processing facility at the WSCP and other sites was also disposed of there. Radioactive materials included drummed wastes, uncontained wastes, building rubble, and contaminated process equipment.

In February 1985, the DOE proposed to designate the control and decontamination of the WSS as a major project, and on May 14, 1985, it was so designated. In October 1985, custody of the WSCP was transferred to the DOE. A project management contractor for the WSSRAP was selected in February 1986, and a DOE project office was established on the site in July 1986. The project management contractor, M-K Ferguson Company (MK-F), assumed control of the WSS on October 1, 1986.

On October 15, 1985, the EPA proposed to include the WSQ on the National Priorities List (NPL), and on July 30, 1987, it was listed. The WSCP/WSRP was also listed on the NPL in March 1989.

The remedial actions to be carried out by the DOE at the WSS are subject to EPA oversight under CERCLA as amended by the Superfund Amendments and Reauthorization Act (SARA). Region VII of the EPA is responsible for oversight of the project.

2 PHYSICAL CHARACTERISTICS OF THE WELDON SPRING SITE

2.1 REGIONAL PHYSIOGRAPHY

The Weldon Spring Chemical Plant, Raffinate Pits and Vicinity Properties (WSCP/WSRP/WSVP) is situated at the southern edge of a major Pleistocene glacial geomorphic feature known as the Dissected Till Plains. This area is characterized by gently rolling topography. South of the WSCP/WSRP, the topography changes dramatically from that of the Dissected Till Plains to the rugged Salem Plateau, which is characterized by narrow ridges and valleys and short, steep streams (Kleeschulte and Emmett, 1986a).

A topographic ridge dividing the Missouri and Mississippi river valleys bisects the raffinate pits and chemical plant area. This divide corresponds to the transition area where the terrain changes from that of the Dissected Till Plains to that of the Salem Plateau.

The Missouri River floodplain to the south of the Weldon Spring Quarry (WSQ) is characteristically flat or gently sloping and densely vegetated.

2.2 INTRODUCTION TO LOCAL GEOLOGY

The surface of the region is covered almost entirely by unconsolidated materials consisting primarily of alluvium, loess, interglacial sediments, glacial drift, and weathered rock. Overburden materials in the upland areas range in thickness from 0 to 50 feet. Alluvial material occurs in drainages. The major floodplains are covered by up to 100 feet of alluvium.

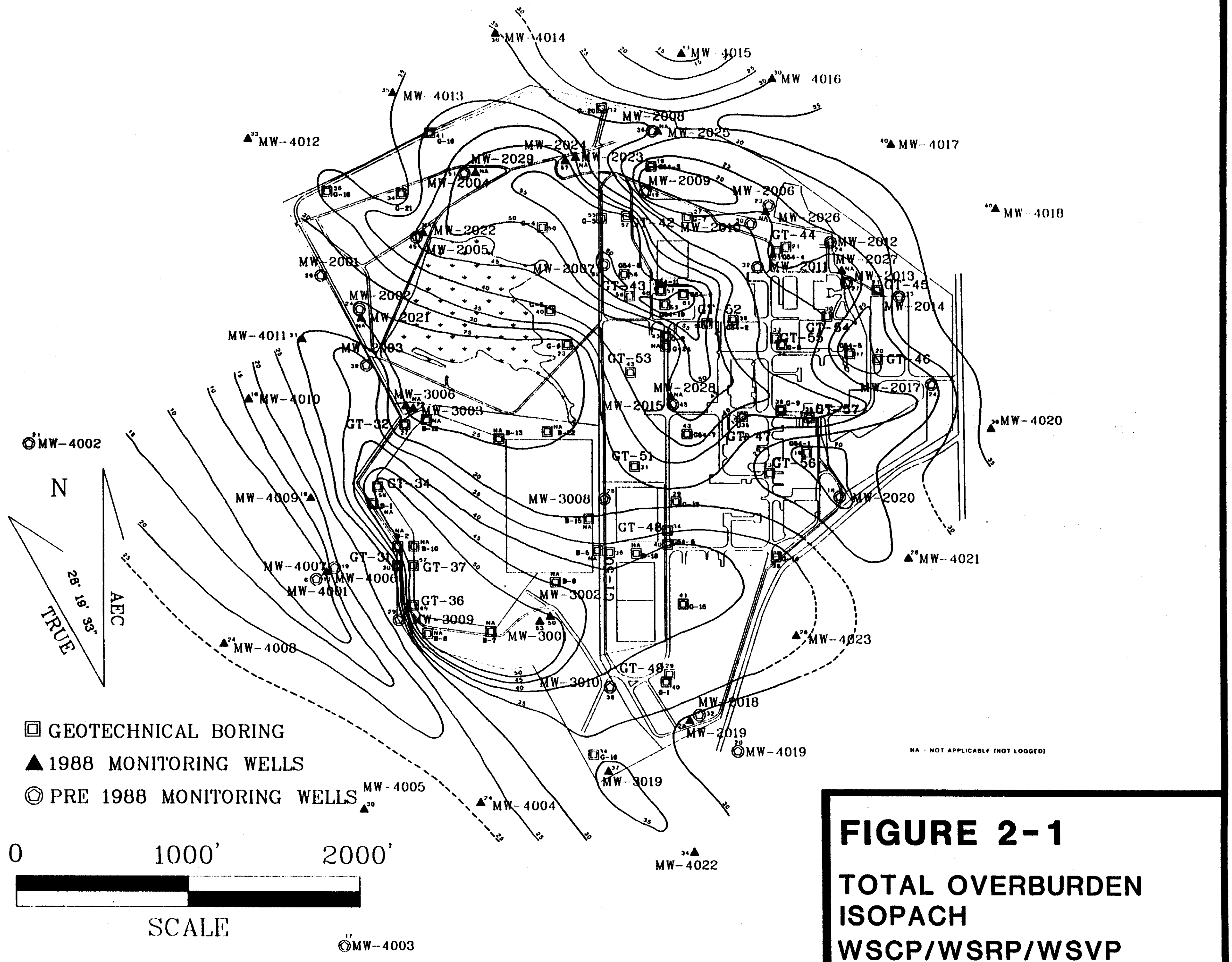
Various unconsolidated sediments overlie bedrock at the Weldon Spring Site (WSS). Exposed bedrock formations at or near the WSS range in age from the Mississippian System, Meramecian Series Salem Limestone to the Ordovician System, Champlainian Series, Plattin Limestone.

No faults cross the WSCP/WSRP/WSVP as evidenced by maps of the exposed bedrock units (MKF, 1987b). Roberts (1951) has identified two major joint sets in the area, one trending between N30°E and N72°E and the other trending between N30°W and N65°W. These joints are present in the Burlington-Keokuk Limestone, the Chouteau Formation, and the Kimmswick Formation. Krummel (1956) and Kleeschulte and Emmett (1986a) indicate jointing is vertical or nearly vertical.

The rocks in the area have a regional strike of N60°W and a regional dip of approximately 1/2 degree to the northeast. The regional dip is predominantly from the Ozarks Dome, though several other features influence the dip. The Eureka-House Springs anticline, the nearest structural anomaly feature is located approximately 4 miles to the southeast (BNI, 1987).

2.2.1 Overburden Geology of the Weldon Spring Chemical Plant, Raffinate Pits, and Vicinity Properties

Overburden materials at the site are composed of fill material, loess, glacial tills, interglacial sediments, and residuum. The thickness of the overburden ranges from 15 to 60 feet and is controlled both by surface erosional features and bedrock topography. The overburden is generally thickest in the north central portion of the site and thinnest in the eastern third of the site (Figure 2-1). Six units may be distinguished in the overburden soils on the basis of physical characteristics observed during sampling and laboratory testing.



□ GEOTECHNICAL BORING

▲ 1988 MONITORING WELLS

◎ PRE 1988 MONITORING WELLS

0 1000' 2000'

SCALE

FIGURE 2-1

TOTAL OVERBURDEN ISOPACH WSCP/WSRP/WSVP

Topsoil/Fill. The uppermost overburden unit is composed of topsoil and fill material. This unit ranges up to 30 feet in thickness. The topsoil fraction is widespread and ranges up to 3.5 feet in thickness. It is generally a black, organically rich clayey silt to silty clay. The thickness of the fill portion varies greatly because of its use as construction material for the raffinate pit dikes, Ash Pond dike, and recontouring of low areas prior to construction of the site buildings. The fill composition varies but is primarily clayey silt which is believed to have originated on or near the site.

Loess. Underlying the topsoil/fill unit is an upper Pleistocene loess unit that is distributed sporadically due to predepositional topography, post-depositional erosion, and extensive reworking of site soils during site preparation and construction. Subsurface data indicate that loess ranges up to 10.5 feet in thickness. The unit is composed of a low plasticity silt to clayey silt with very minor amounts of sand.

Ferrelview Formation. The Ferrelview Formation is believed to be a mid-Pleistocene glacial till plain sediment (Howe and Heim, 1969). The unit is present across most of the site and ranges up to 22 feet in thickness. It consists of a mottled gray and dark yellowish-orange silty clay to clayey silt. The unit is often stiff and plastic. Iron oxide nodules and manganese oxide precipitates (pyrolusite) are common. Distribution of the precipitate may be controlled by joint surfaces developed during consolidation. Unmineralized fracture surfaces also exhibit slikensides in many cases. Laboratory tests for particle size distribution indicate a majority of silt and clay-sized particles in this unit with minor sand and fine gravel.

Clay Till. The clay till underlies the Ferrelview Formation and is the most areally extensive overburden unit on the site. It ranges in thickness to 30 feet and is found in almost all boreholes and trenches on site. This unit is an older Pleistocene glacial till than the Ferrelview and is composed of yellowish-brown silty clay and clayey silt with some sand and rounded pebbles of chert and igneous and metamorphic detritus. Material in this unit is very stiff and moderately to highly plastic. Manganese oxide precipitates (pyrolusite) are abundant.

Basal Till. The basal till unit is the lowest member of the Pleistocene glacial till sediments found on the site. It underlies the clay till and is found mainly on the western and north central portions of the site. Deposition of the basal till unit may have been influenced by bedrock topography since the unit is generally thin or absent in areas of higher bedrock elevations and thicker where bedrock elevations are lower. The basal till ranges in thickness up to 8 feet and can generally be described as a yellowish-brown sandy, clayey, silty gravel having angular chert in a poorly bound matrix.

Residuum. The residuum unit is located beneath the basal till at the base of the unconsolidated overburden. The residuum is interpreted to be the weathering product of the underlying cherty argillaceous limestone. The unit ranges in thickness up to 26 feet. The residuum is typically a distinctive red to minor yellow gravelly clay to gravelly silt. The gravel fraction is generally weathered chert fragments but contains minor weathered limestone. Interstitial clay is usually quite plastic and tends to form a tight matrix within the gravel fraction.

2.2.2 Bedrock Geology of the Weldon Spring Chemical Plant, Raffinate Pits, and Vicinity Properties

The Burlington-Keokuk Limestone is the uppermost bedrock unit underlying the WSCP/WSRP. The highest bedrock elevations, at approximately 635 feet above mean sea level (MSL), are under the southeast portion of the WSCP. Due to the presence of overburden deposits, surface topography seems to have developed independently of bedrock elevation and does not necessarily correspond to it. Figure 2-2 is a map of the interpretation of the top of the bedrock elevation at the WSCP/WSRP/WSVP. The map was constructed using lithologic logs from a combination of more than 100 monitoring wells and geotechnical borings.

The Burlington-Keokuk Limestone is vertically fractured with two primary joint sets trending between N30°E and N72°E, and between N30°W and N65°W (BNI, 1987). The Burlington-Keokuk Limestone is a carbonate formation and is locally susceptible to natural solution processes. Solutional features may develop along fractures and bedding planes in this unit (Thornbury, 1969). Thickness of this unit varies from approximately 100 feet to greater than 200 feet. The variability in thickness is attributed to a variance in the depth of weathering of the limestone. The lower unit of the Burlington-Keokuk Limestone is slightly weathered to fresh, slightly fractured, brownish-gray to gray, and contains approximately 30% chert. From a study of the core samples, the unit appears to be massive. Solution features are limited to occasional vugs in the upper portion. Pressure solution features and/or shale interbeds are common (BNI, 1987).

Underlying the Burlington-Keokuk Limestone, the Fern Glen Limestone is a thin- to thick-bedded, crystalline to argillaceous limestone. Chert is common in this formation with the occurrence of occasional calcareous shale interbeds. The

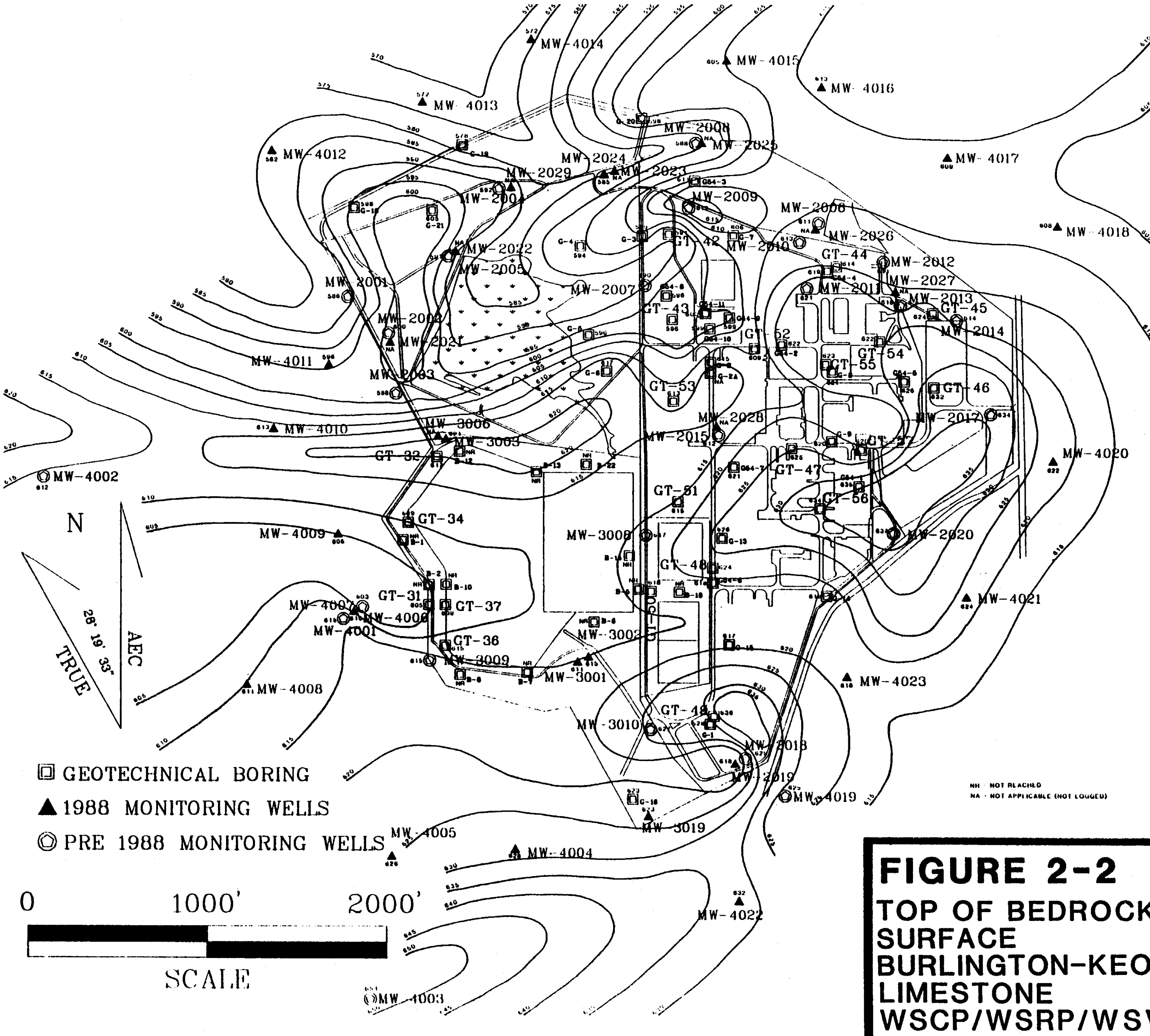


FIGURE 2-2

TOP OF BEDROCK SURFACE
BURLINGTON-KEOKUK LIMESTONE
WSCP/WSRP/WSVP

thickness of this unit at the site is estimated to be approximately 50 feet.

Brief general descriptions of the units from the base of the Fern Glen Limestone down section through the St. Peter Sandstone are listed below and the stratigraphic relationships are demonstrated in a site-specific stratigraphic column (Figure 2-3).

Chouteau Formation	Conformably underlies Mississippian age, Osagean series which includes the Fern Glen Limestone and the Burlington-Keokuk Limestone. Thin-bedded limestone containing a few shale partings and localized argillaceous material and chert. Unconformably overlies the Bushberg Sandstone.
Sulphur Springs Group (Bushberg Sandstone)	Fine to medium-grained quartzose sandstone with variable carbonate content. Unconformably overlies the Kimmswick Limestone.
Maquoketa Formation	Dark grey to blue calcareous mudstone/shale.
Kimmswick Limestone	Composed of thick-bedded, high-purity limestone with local concentration of chert.
Decorah Formation	Thin-bedded argillaceous limestone with intercalated calcareous shales. Thin bed of metabentonite separates the Plattin and Decorah formations.
Plattin Limestone	Thin- to thick-bedded, microcrystalline to fine-grained limestone.

AGE	UNIT	THICK	LITH	DESCRIPTION
MISSISSIPPIAN	BURLINGTON-KEOKUK	100-200		LIMESTONE,CHERTY, WHITE-LT.GRAY THICKLY BEDDED, VERY FINE TO VERY COARSELY CRYSTALLINE, FOSSILIFEROUS
	FERN GLEN	45-70'		LIMESTONE, DOLOMITIC IN PART, YEL GRAY-LT GRAY GREEN,VERY FINE-VERY COARSELY CRYSTALLINE,CHERTY.
	CHOUTEAU	20-70'		DOLOMITIC LIMESTONE,GRAY TO YELLOW BROWN, FINELY CRYSTALLINE,THIN TO MEDIUM BEDDED,ARGILLACEOUS
MISS-DEV.	SULPHUR SPRINGS GROUP	40-55'		SANDSTONE, V.LT.GRAY, VERY FINE GRAINED;SILTSTONE,GRAY BROWN, CALC LIMESTONE, GREEN GRAY, ARGILLACEOUS
ORDOVICIAN	MAQUOKETA?	10-30'		SHALE/MUDSTONE, VERY DK GRAY TO BLUISH GREEN, CALCAREOUS IN PART
	KIMMSWICK	70-100'		LIMESTONE, WHITE TO LT. YELLOW, COARSELY CRYSTALLINE, MEDIUM TO THICKLY BEDDED, HIGHLY FOSSILIFEROUS AND CHERTY AT BASE
	DECORAH	30-60'		SHALE, BLUISH GRAY TO DARK GRAY W/ INTERBEDDED LIMESTONE, VERY FINELY CRYSTALLINE, FOS & CHERTY IN PART
	PLATTIN	100-130'		DOLOMITIC LIMESTONE, LT. GREEN GRAY TO BROWN, VERY FINELY CRYSTALLINE THINLY BEDDED, FOSSILIFEROUS
	JOACHIM	80-100'		INTERBEDDED DOLOMITE, LIMESTONE AND SHALE, LT BROWN, LT GRAY AND GREEN GRAY, VERY FINELY CRYSTALLINE THINLY BEDDED, SANDY AT BOTTOM
	ST. PETER	60-80'		SANDSTONE, LT YELLOW GRAY, VERY FINE GRAINED, WELL ROUNDED AND SORTED, FRIABLE

FIGURE 2-3

GENERALIZED STRATIGRAPHIC COLUMN

Joachim Dolomite	Thin- to thick-bedded dolomite which grades into siltstone.
St. Peter Sandstone	Composed of fine to medium-grained, massive-bedded, quartzose sandstone.

2.2.3 Overburden Geology of the Weldon Spring Quarry

The unconsolidated upland material overlying bedrock consists of 10 to 40 feet of silty clay soil developed from loess deposits. A residual soil is present in some areas between the silty clay and bedrock. The upland soils near the WSQ are generally not saturated and are therefore not monitored.

The Missouri River Valley alluvium contains sediments varying from clays and silts through sands, gravels, cobbles and boulders. The maximum alluvium depth near the WSQ is approximately 100 feet. The alluvium truncates at the base of the bedrock bluffs which are comprised of Upper Ordovician carbonate units. Figure 2-4 shows silts and clays with minor amounts of sand as the primary sediments between the bluff and the Femme Osage Slough. The sands and gravels (50 to 60 feet thick) truncate against the bluffs southeast of the slough near the WSQ.

2.2.4 Bedrock Geology of the Weldon Spring Quarry

The WSQ bedrock consists of three distinct Ordovician formations. In down-section order, they are the Kimmswick Formation, the Decorah Formation and the Plattin Formation. The Bushberg Formation, a Devonian sandstone, overlies the Kimmswick Formation to the north, west and east of the WSQ at higher elevations but is not present at the WSQ.

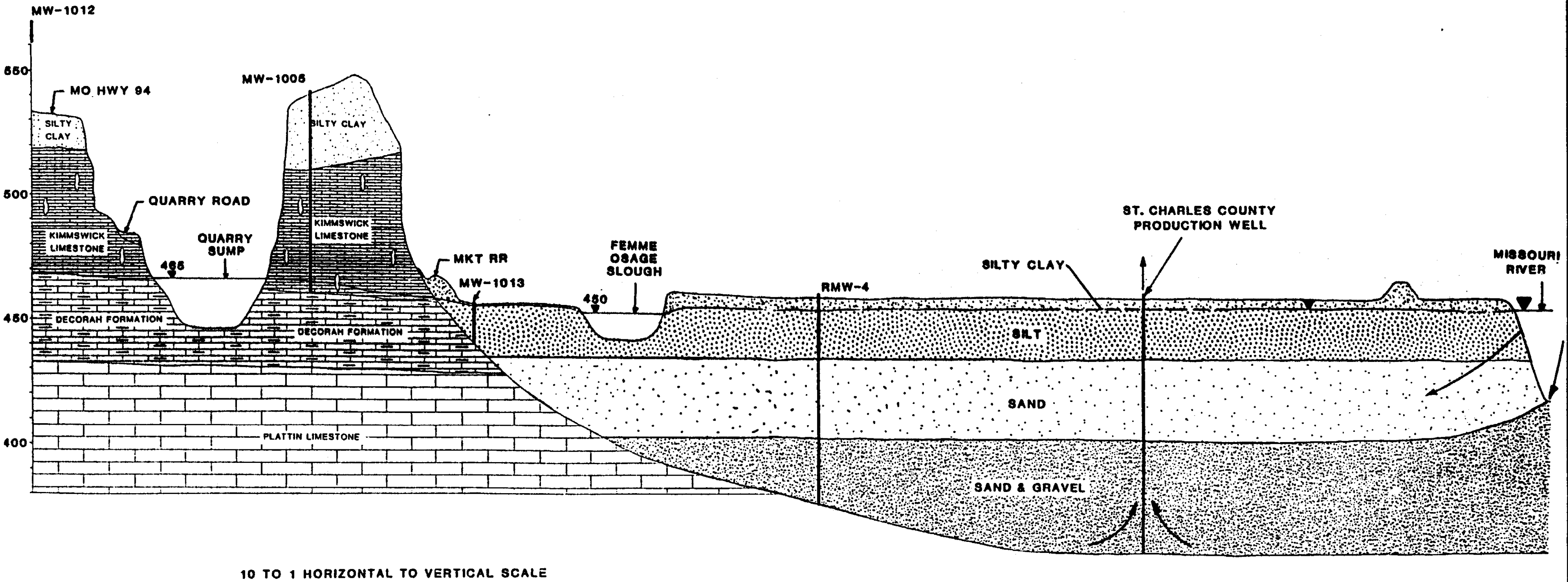


FIGURE 2-4

STRATIGRAPHIC/GEOLOGIC CROSS SECTION OF WSQ (MISSOURI RIVER VALLEY ALLUVIUM)

The Kimmswick Formation is a coarsely crystalline, light gray, massive limestone with numerous solution-enlarged joints and cavities. The predominant joint set trends approximately N70°W (Berkeley Geosciences, 1984). The Decorah Formation consists of interbedded limestones and green shale. This bedrock unit is approximately 30 feet thick and contains horizontal fractures.

The Plattin Formation is a thinly bedded, finely crystalline gray limestone. Thickness varies from 100 to 125 feet in the vicinity of the WSQ.

2.3 SURFACE WATER HYDROLOGY

2.3.1 Surface Water Hydrology of the Weldon Spring Chemical Plant, Raffinate Pits and Vicinity Properties

The WSCP/WSRP is located on the surface drainage divide between the Mississippi and Missouri rivers. Drainage from the northern and western portions of the WSCP/WSRP flows northward to tributaries of Schote Creek, a tributary of the Mississippi River. The southeastern portion of the area drains generally southward to unnamed tributaries which flow to the Missouri River. Major surface water and drainage features of the region are shown in Figure 2-5.

The area, which is on the Mississippi River watershed drainage, is divided into three major drainage basins: the Ash Pond area, the Frog Pond area, and the raffinate pit vicinity. Runoff from both the Ash Pond and raffinate pit vicinity drainages enters an unnamed tributary to Schote Creek which flows into Lake 35 on the August A. Busch Wildlife Area. Both streams lose water to the subsurface (Dean, 1983a and 1985). Some of this lost flow resurfaces at Burgermeister Spring which feeds Lake 34, also on the August A. Busch Wildlife Area (Dean, 1984a).

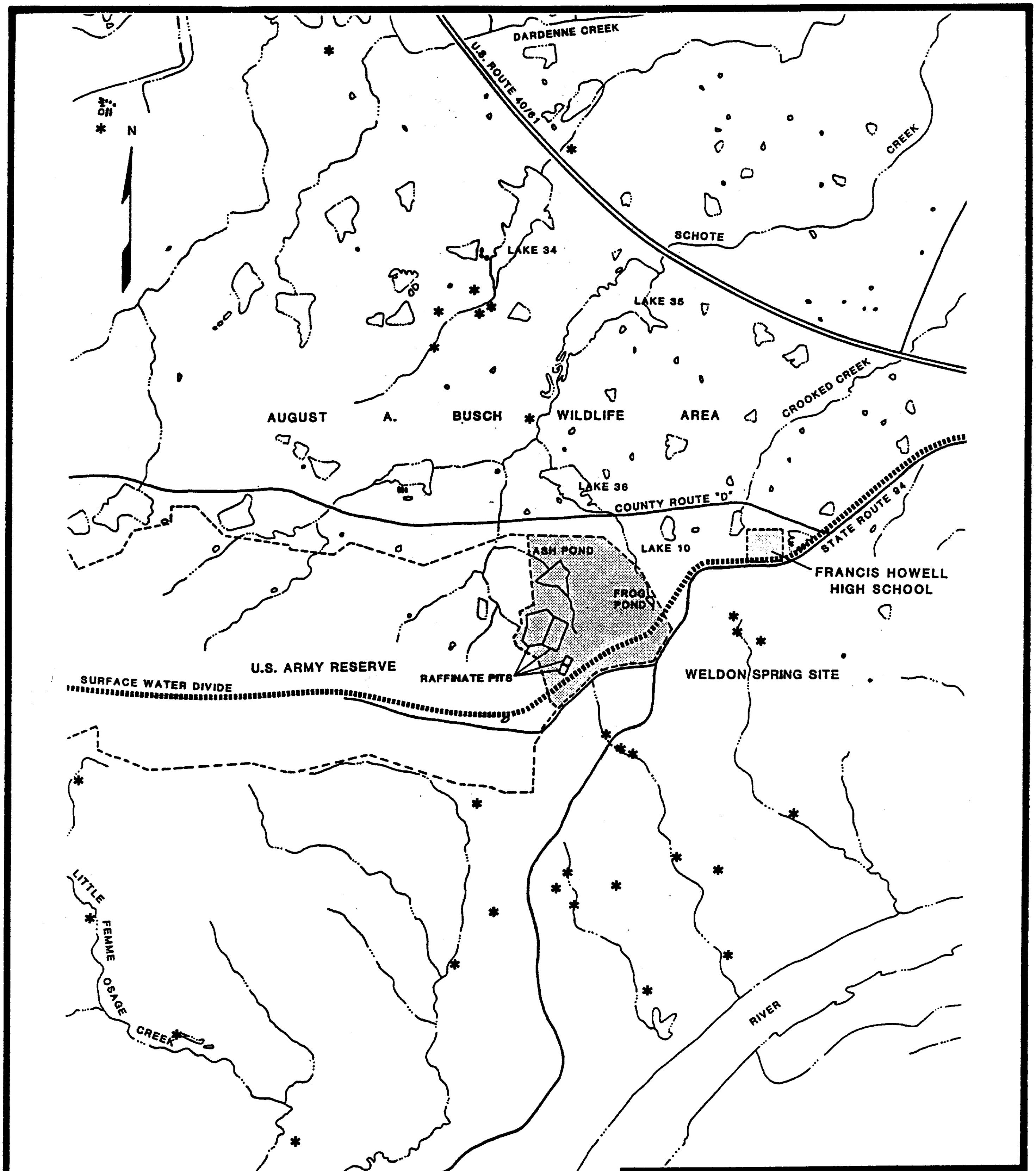


FIGURE 2-5

SURFACE WATER, DRAINAGE FEATURES, AND SPRINGS IN THE WSS AREA

Surface water from Frog Pond exits the WSCP and flows into Lake 36. Overflow from Lake 36 enters Schote Creek, which then flows into Lake 35. Lake 35 overflows to Schote Creek only during extreme precipitation events. Schote Creek joins Dardenne Creek just east of Highway K. These features are depicted in Figure 2-2.

Lake 35 has been losing water to the subsurface since its construction. In early 1987, a small swallow hole opened near the headwaters of Lake 35. Missouri Department of Natural Resources dye studies determined that some of the lost water resurfaces at Burgermeister Spring and flows into Lake 34 (MDNR, 1989). Lake 34 outflow enters an unnamed tributary of Dardenne Creek. Dardenne Creek flows northeast to the Mississippi River.

Approximately 20 acres of the chemical plant area are within the Missouri River watershed. Drainage of this area is via the southeast drainage easement, an intermittent stream valley approximately 1.5 miles long.

There are four raffinate pits in the WSRP area with surface water standing in all of the pits. Recharge estimates for water in the raffinate pits are available for the months of April through October over a two-year period (1983-1984) (BNI, 1986). When evapotranspiration is included, these data give an average loss from the pits of less than 1 mm depth per day. Water budget calculations and groundwater geochemistry indicate the raffinate pits are leaking.

2.3.2 Surface Water Hydrology of the Weldon Spring Quarry Area

The WSQ is located approximately 1 mile northwest of the Missouri River. All runoff from land surfaces in the quarry area not lost to evapotranspiration eventually reaches the

Missouri River hydrologic system. In addition to the Missouri River, surface streams in the immediate vicinity of the WSQ include the Femme Osage Creek and the Little Femme Osage Creek. These streams ultimately flow into the Missouri River.

The Femme Osage Slough is located south of the WSQ. It consists of a 1.5-mile section of the former Femme Osage Creek that was dammed at both ends between 1960 and 1963 by the University of Missouri (MKF and JEG, 1987). The water level of the slough is affected by the levels of the Missouri River, the subsequent groundwater elevation in the alluvial aquifer and other recharge-discharge factors such as precipitation, evaporation and evapotranspiration.

The only surface water feature in the WSQ is a 0.5-acre pond. The pond contains approximately 3 million gallons of water (BNI, 1986). Inflow into the WSQ is mainly attributed to direct rainfall. The high rim around the WSQ prevents the entry of surface runoff from the surrounding area. Drainage from the WSQ and pond is primarily through the subsurface, with minor surface drainage possible from the southern and western rims.

2.4 HYDROGEOLOGY

Near-surface groundwater occurs in the overburden, bedrock, and the alluvium of the floodplains. Groundwater also occurs at depth in bedrock. This section summarizes information available in existing reports related to the hydrogeology of the area. Information on groundwater occurrences and flow, including variations, is presented with a discussion of potential areas of recharge and discharge in the area.

2.4.1 <u>Aquifers Defined</u>

The U.S. Geological Survey (USGS) delineates three principal aquifer systems in the general area: the alluvial aquifers, the Mississippi/Devonian (M/D) bedrock aquifer system, and the Ordovician/Cambrian (O/C) bedrock aquifer system (Table 2.1) (Kleeschulte and Emmett, 1986b). Figure 2-6 graphically represents the hydrostratigraphy of the Weldon Spring area.

2.4.1.1 Alluvial Aquifers

The alluvial aquifers include the saturated sands, gravels, and silts in the alluvium of the Missouri and Mississippi rivers and the alluvium of tributary creeks where significant groundwater yields can occur.

The hydraulic properties of the alluvial aquifer are locally variable depending upon the thickness and grain size distribution of the alluvium. In general, the alluvium of the Missouri River floodplain becomes finer, less permeable and thinner laterally from the Missouri River to the north, near the Femme Osage Slough (Kleeschulte and Emmett, 1987).

Groundwater levels in the aquifer are influenced by the flow rate and stage of the Missouri River. Water produced from this aquifer is derived mostly from Missouri River water infiltration and, to a lesser extent, from creeks, rainfall, and possibly, local recharge from the bedrock aquifer. The potentiometric surface fluctuates in response to the stage of the Missouri River. This indicates that the Missouri River is the primary recharge source for this aquifer (Layne Western, 1986 and Berkeley Geosciences, 1984).

ORDOVICIAN/CAMBRIAN AQUIFER

CONFINING SEQUENCE

ORDOVICIAN	UPPER	Maquoketa Shale	0-650	0-75	30-50	Calcareous or dolomitic shale; typically thinly laminated, silty, with shaly limestone lenses.	Leaky confining layer	Yields small quantities of water to wells.
ORDOVICIAN	MIDDLE	Kimmswick Limestone	0-710	0-140	90-100	Limestone; white to light gray, coarsely crystalline, medium- to thickly bedded. Cherty near base.	Leaky confining layer	Yields small to moderate quantities of water to wells (10-50 gal/min).
ORDOVICIAN	MIDDLE	Decorah Formation	0-810	0-35	30	Interbedded green and yellow shale with thin beds of limestone.	Leaky confining layer	
ORDOVICIAN	MIDDLE	Plattin Limestone	0-840	0-195.	100-125	Limestone; light to dark gray, finely crystalline. Thinly bedded; weathers with pitted surface.	Leaky confining layer	
ORDOVICIAN	MIDDLE	Joachim Dolomite	0-950	0-135	90-110	Dolomite; yellowish-brown, silty, thin- to thickly bedded. Grades into siltstone, shales common.	Leaky confining layer	
ORDOVICIAN	MIDDLE	St. Peter Sandstone	0-1,070	0-250	120-150	Quartz sandstone; yellowish-white to white, fine- to medium-grained, massively bedded.	Deep bedrock aquifer	Yields moderate quantities of of water to wells (10-140 gal/min). Everton Formation discontinuous.
ORDOVICIAN	MIDDLE	Everton Formation	0-850	0-65	0	Sandy dolomite.	Deep bedrock aquifer	
ORDOVICIAN	LOWER	Powell Dolomite	0-950	0-65	50-60	Dolomite; medium to finely crystalline, often sandy, occasionally cherty or shaly.	Deep bedrock aquifer	Generally yields small quantities of water to wells (<10 gal/min).
ORDOVICIAN	LOWER	Cotter Dolomite	0-1,250	75-275	200-250	Dolomite; light gray to light brown, medium to finely crystalline, cherty. Argillaceous, interbedded with green shale.	Deep bedrock aquifer	
ORDOVICIAN	LOWER	Jefferson City Dolomite	100-1,500	145-225	160-180	Dolomite; light brown to brown, medium to finely crystalline.	Deep bedrock aquifer	
ORDOVICIAN	LOWER	Roubidoux Formation	350-1,700	150-170	150-170	Dolomitic sandstone.	Deep bedrock aquifer	Yields moderate to large quantities of water to wells (10-300 gal/min).
ORDOVICIAN	LOWER	Gasconade Dolomite	500-1,850	250	--	Cherty dolomite; Gunter Sandstone Member is arenaceous.	Deep bedrock aquifer	Gunter Sandstone Member is about 30 feet thick.
CAMBRIAN	UPPER	Eminence Dolomite	750-2,100	190	--	Dolomite; medium- to massively bedded, light gray, medium- to coarse-grained.	Deep bedrock aquifer	Yields moderate to large quantities of water to wells (10-500 gal/min).
CAMBRIAN	UPPER	Potosi Dolomite	950-2,250	100	--	Dolomite; massive, thickly bedded, medium- to fine-grained. Abundant quartz druse.	Deep bedrock aquifer	Freshwater only in south-west part of St. Charles County and saline water elsewhere in county.
CAMBRIAN	UPPER	Doe Run and Derby Dolomites[1]	1,050-2,350	140	--	Dolomite; thinly- to medium-bedded alternating with thinly bedded silt-stone and shale.		Hydrologic characteristics unknown in St. Charles County. Is a confining bed elsewhere in State.
CAMBRIAN	UPPER	Davis Formation	1,200-2,500	170	--	Shale, siltstone, fine-grained sandstone, dolomite, and lime-stone conglomerate.		
CAMBRIAN	UPPER	Bonneterre Dolomite	1,350-2,650	430	--	Dolomite; typically light gray, medium- to fine-grained, medium-bedded.		Yields unknown in St. Charles County; however, water probably is saline.
CAMBRIAN	UPPER	Lamotte Sandstone	1,800-3,100	460	--	Predominantly quartzose		
PRECAMBRIAN		Igneous rocks undifferen-tiated	2,200-3,500		--	Igneous rocks.		Yields no water.

[1] Designated Derby-Doerun Dolomite by the Missouri Division of Geology and Land Survey.

TABLE 2.1
GENERALIZED DESCRIPTION OF THE LITHOLOGIC AND HYDROLOGIC PROPERTIES OF THE AQUIFERS

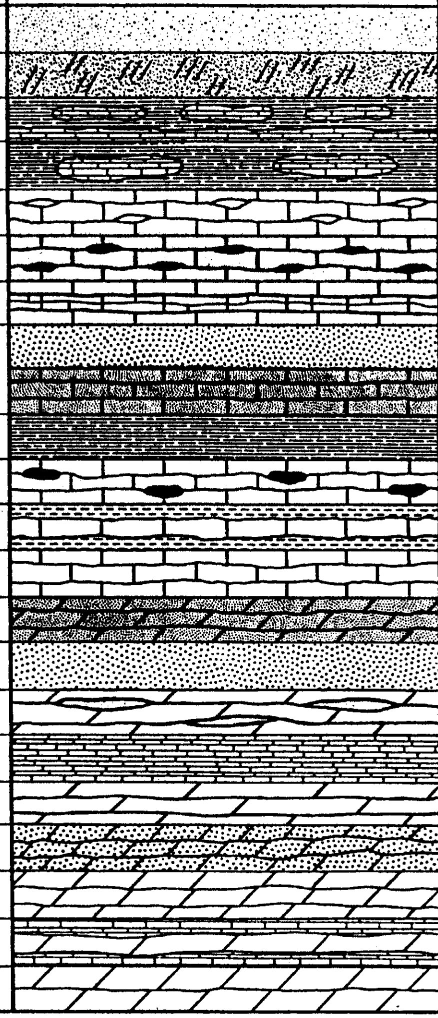
[Modified from Koenig (1961); Miller and others (1974); gal/min, gallons per minute; --, insufficent data to make estimate; <, less than; Typical thickness refers to thickness of formation normally encountered while drilling and does not include extremes]

MISSISSIPPIAN/DEVONIAN AQUIFER

System	Series	Stratigraphic unit	Depth from ground level to top of formation, in feet	Thickness, in feet	Typical thickness, in feet	Physical characteristics		Remarks
QUATERNARY	HOLOCENE	Alluvium	0	0-65	10-30	Gravelly, silty loam over occasionally gravelly, silty clay loam.	Alluvial aquifers	Deposits underlie tributaries to Missouri and Mississippi rivers.
			0	65-120	100-110	Silty loam, clay, and sanc over sand and gravelly sand.		Deposits underlying Missouri and Mississippi River flood plains generally yield large quantities of water to wells. (600-2,600 gal/min).
	PLEISTOCENE	Loess and glacial drift	0	0-150	5-30 30-60	Silty clay, silty loam, clay, or loam over residuum and bedrock, or both		Yields little water to wells (<5 gal/min).
PENNSYLVANIAN		Undifferentiated	0-120	0-75	--	Partly silty red shale with purplish-red to light gray clay.		Limited occurence. Yields small quantities of water to wells (<1-10 gal/min).
MISSISSIPPIAN	MERAMECIAN	St. Louis Limestone	0-120	0-105	70-75	Limestone; white to light gray, lithographic to finely crystalline, medium- to thickly bedded. Contains some shale.	Shallow bedrock aquifer	
		Salem Limestone	0-225	0-140	90-130	Limestone; light gray white, fine to coarsely crystalline, cross-bedded. Some siltstone and shale lower part.		Individually, the rock units yield small to moderate quantities of water to wells (5-50 gal/min). Collectively, these units yield sufficient water to supply most domestic and stock needs.
		Warsaw Formation	0-345	0-95	70-90	Calcareous shale and interbedded shaly limestone, grades downward to shaly dolomitic limestone.		
	OSAGEAN	Keokuk and Burlington Limestones	0-405	0-220	160-200	Limestone; white to bluish-gray, medium to coarsely crystalline, thickly bedded. Cherty.		
		Fern Glen Limestone	0-500	0-85	50-70	Limestone; yellowish-brown, fine-grained, medium- to thickly bedded. Contains appreciable chert.		
	KINDERHOOKIAN	Chouteau Limestone	0-580	0-105	50-70	Dolomitic limestone; gray to yellowish-brown, fine-grained, thinly to medium-bedded.		
DEVONIAN	UPPER	Bushberg Sandstone	0-625	0-20	5-15	Quartz sandstone; reddish-brown, fine- to medium-grained, friable.		Yields small to moderate quantities of water to wells. (5-50 gal/min).
		Lower part of Sulphur Spring Group undifferentiated	0-625	0-60	35-40	Calcareous siltstone and sand-stone with oolitic limestone with some dark, hard, carbonaceous shale.		Sulphur Spring Group also includes Glen Park and Grassy Creek Formations. Units in the Sulphur Spring Group are the usage of the Missouri Division of Geology and Land Survey.

CONTINUED

TABLE 2.1
GENERALIZED DESCRIPTION OF THE LITHOLOGIC AND HYDROLOGIC PROPERTIES OF THE AQUIFERS

SYSTEM	SERIES	STRATIGRAPHIC UNIT	TYPICAL THICK (FT)	LITHOLOGY	HYDROSTRATIGRAPHIC UNIT
QUARTERNARY	HOLOCENE	ALLUVIUM	0.5-4		ALLUVIAL AQUIFER
	PLEISTOCENE	LOESS & GLACIAL TILL	15-55		(unsaturated) *
MISSISSIPPIAN	MERAMECIAN	SALEM FORMATION	0-15		(unsaturated) *
		WARSAW FORMATION	60-80		
	OSAGEAN	BURLINGTON-KEOKUK LIMESTONE	100-200		MISSISSIPPIAN-DEVONIAN AQUIFER SYSTEM
		FERN GLEN FORMATION	45-70		
	KINDERHOOKIAN	CHOUTEAU GROUP	20-50		
DEVONIAN	UPPER	BUSHBERG SANDSTONE	40-55		
		LOWER SULPHUR SPRINGS GROUP (UNDIF.)			
ORDOVICIAN	CINCINNATIAN	MAQUOKETA SHALE	10-30		ORDOVICIAN LEAKY CONFINING UNIT
	CHAMPLAINIAN	KIMMSWICK LIMESTONE	70-100		
		DECORAH GROUP	30-60		
		PLATTIN LIMESTONE	100-130		
		JOACHIM DOLOMITE	80-105		
		ST. PETER SANDSTONE	120-150		ORDOVICIAN-CAMBRIAN AQUIFER SYSTEM
	CANADIAN	POWELL DOLOMITE	50-60		
		COTTER DOLOMITE	200-250		
		JEFFERSON CITY DOLOMITE	160-180		
		ROUBIDOUX FORMATION	150-170		
		GASCONADE DOLOMITE	250		
CAMBRIAN	UPPER	EMINENCE DOLOMITE	200		
		POTOSI DOLOMITE	100		

* THESE UNITS ARE BELIEVED TO BE UNSATURATED IN THE WSS VICINITY

MODIFIED FROM : MKF & JEG, 1989; WHITFIELD ET. AL, 1989; KLEESHULTE AND EMMETT, 1987

FIGURE 2-6
GENERAL STRATIGRAPHY AND HYDROSTRATIGRAPHY OF THE WELDON SPRING AREA

2.4.1.2 Mississippian/Devonian Bedrock Aquifer System

The M/D bedrock system consists of saturated rock of Mississippian and Devonian age which includes formations from the Burlington-Keokuk Limestone down through the Bushberg Sandstone. Near the WSQ, shallow groundwater occurs in the Chouteau Formation down-column to the Plattin Limestone in the leaky confining layer of the O/C aquifer. Individual units or zones within the leaky confining layer may yield low to moderate amounts (1 to 50 gpm) of potable water on a local basis. The confining sequence is approximately 400 feet thick (Kleeschulte and Emmett, 1986a).

The M/D bedrock aquifer in the WSCP/WSRP/WSVP area is important for two reasons: First, it is shallow, hence in close proximity to contaminant sources, and second, its upper portion is weathered and fractured, hence of a higher hydraulic conductivity than deeper, unweathered M/D zones. The higher conductivity means that contaminants entering this upper zone may potentially become widely disbursed in the shallow groundwater system. The regional potentiometric surface of the M/D aquifer is illustrated in Figure 2-7. Note the groundwater divide of the M/D aquifer extends through the Weldon Spring region. A potentiometric surface of the Burlington-Keokuk Limestone at the WSCP/WSRP/WSVP is presented in Figure 2-8.

2.4.1.3 Ordovician/Cambrian Bedrock Aquifer System

The O/C aquifer system consists of saturated Ordovician and Upper Cambrian rocks which include sediments from the top of the Maquoketa Shale down through the Potosi Dolomite. The upper part of the O/C aquifer system is a leaky confining layer from the top of the Maquoketa to the bottom of the Joachim Dolomite. Individual formations or members in this group may be classified as low yielding aquifers (Kleeschulte and Emmett, 1986a).

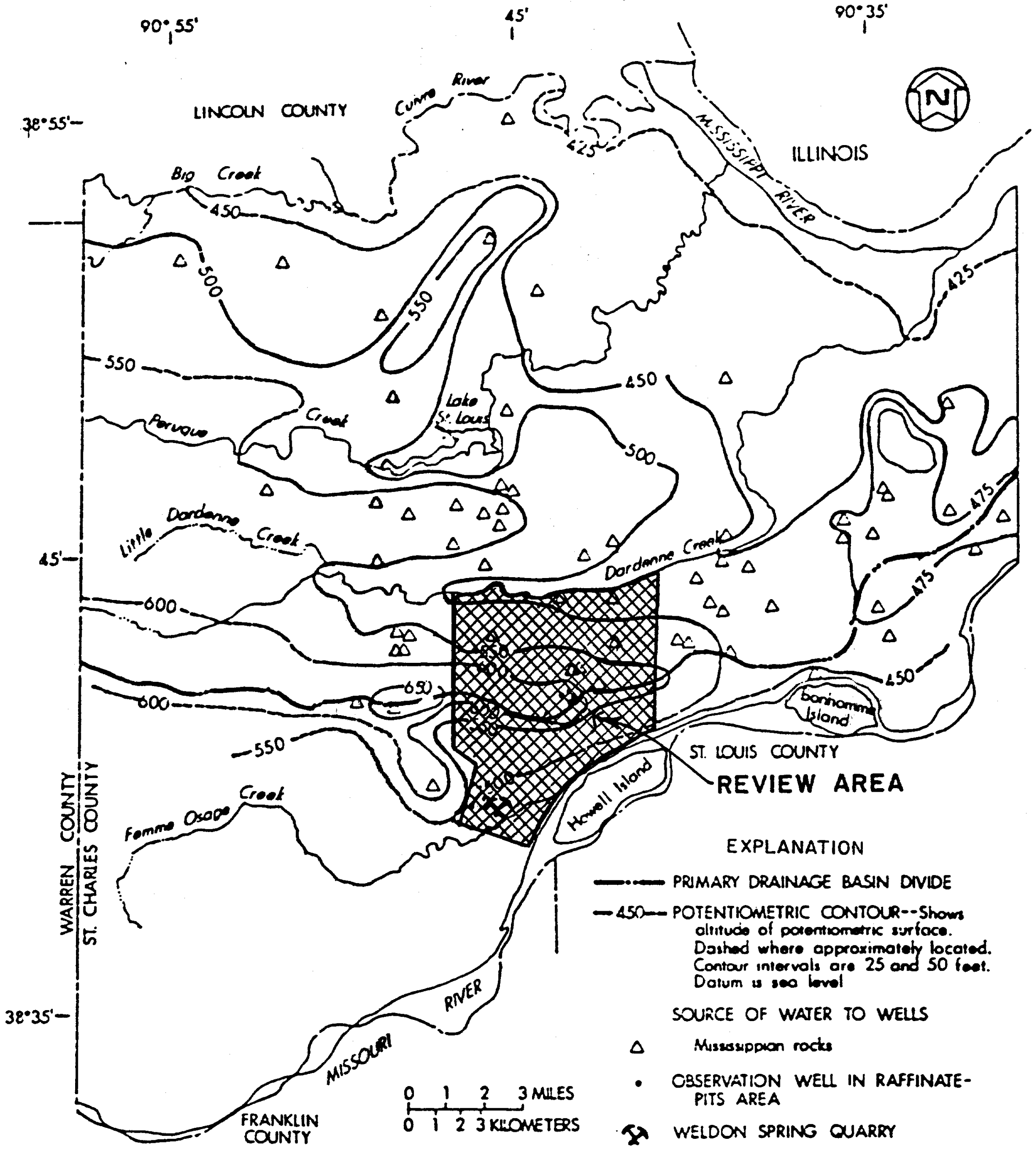


FIGURE 2-7

POTENTIOMETRIC SURFACE OF THE MISSISSIPPIAN/DEVONIAN BEDROCK AQUIFER, SUMMER 1984

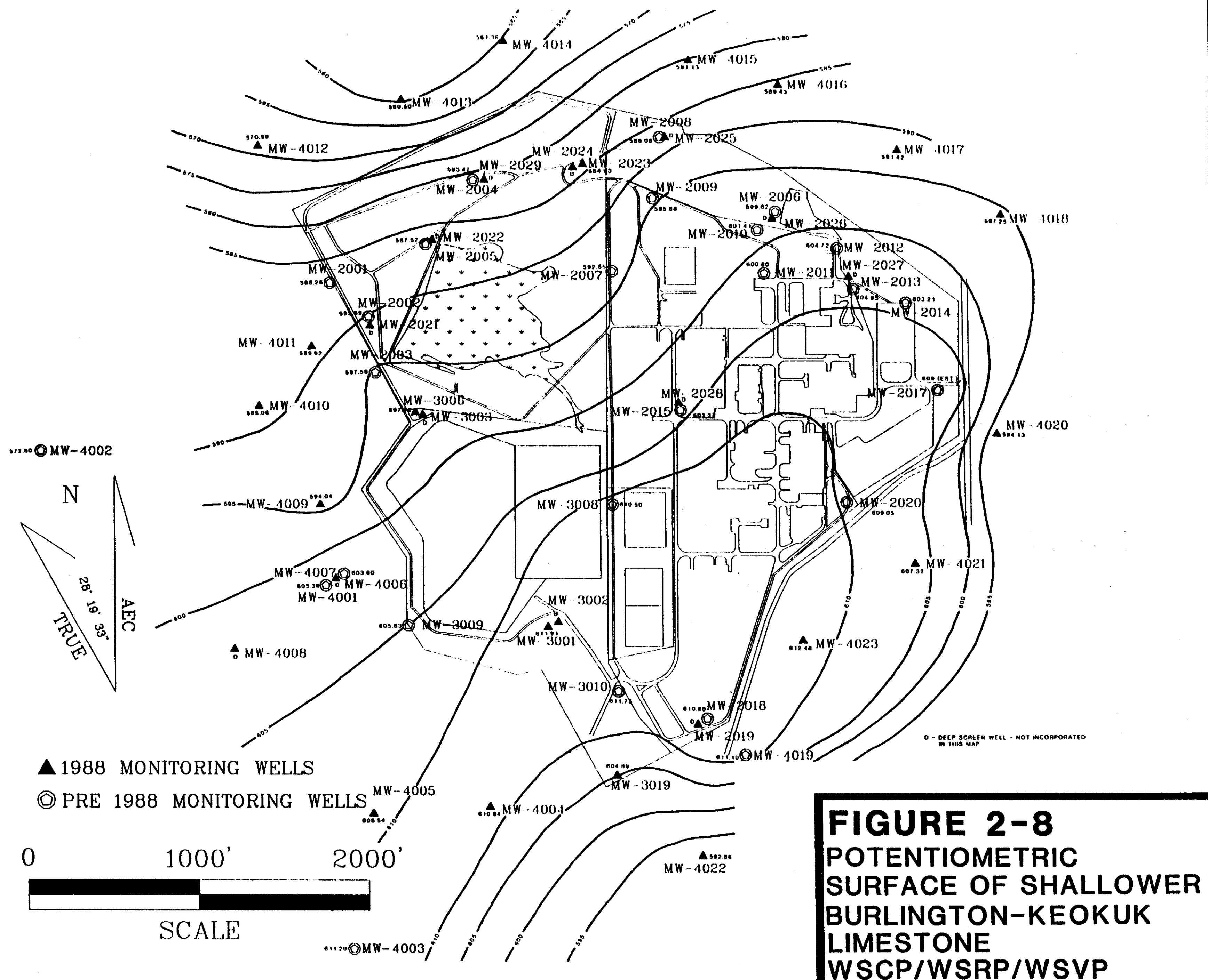


FIGURE 2-8
POTENTIOMETRIC SURFACE OF SHALLOWER BURLINGTON-KEOKUK LIMESTONE WSCP/WSRP/WSVP

The O/C aquifer system is approximately 1,000 feet thick and consists of the Ordovician St. Peter Sandstone through the Upper Cambrian Potosi Dolomite (Kleeschulte and Emmett, 1987). Yields from this aquifer range from 10 to 500 gpm (BNI, 1987). Recharge to the O/C bedrock aquifer occurs primarily as direct infiltration of precipitation where the Ordovician units outcrop southwest of the Weldon Spring area. Additionally, recharge occurs where losing stretches of streams penetrate the aquifer near the outcrop area, and/or as leakage from superjacent aquifers under conditions of downward hydraulic gradient. Discharge from the O/C bedrock aquifer principally occurs as underflow to the alluvial and bedrock aquifers under upward hydraulic gradient conditions, and as evapotranspiration and seepage to springs and streams where the O/C aquifer crops out.

The regional potentiometric surface map of the O/C aquifer system was created by Kleeschulte and Emmett (1986a) (Figure 2-9). A groundwater divide in the O/C aquifer system exists just north of the WSS. A large groundwater depression (due to pumping) is present four miles north of the divide. The aquifer system has varying lithologies including shales, limestones, dolomites, and sandstones.

2.4.1.4 Overburden Aquifer System

Groundwater is present locally in both the unconsolidated formations and the shallow bedrock in the vicinity of the WSCP/WSRP/WSVP. Groundwater is present in the overburden in areas bordering Raffinate Pits 3 and 4, indicating these surface-water impoundments are leaking and perhaps forming a groundwater mound or perched groundwater conditions in the immediate area. In most locations at the WSCP/WSRP/WSVP, groundwater occurs first in the shallow bedrock aquifer. Depths to non-artificially mounded groundwater at the WSCP/WSRP/WSVP vary from about 30 to 65 feet below the ground surface.

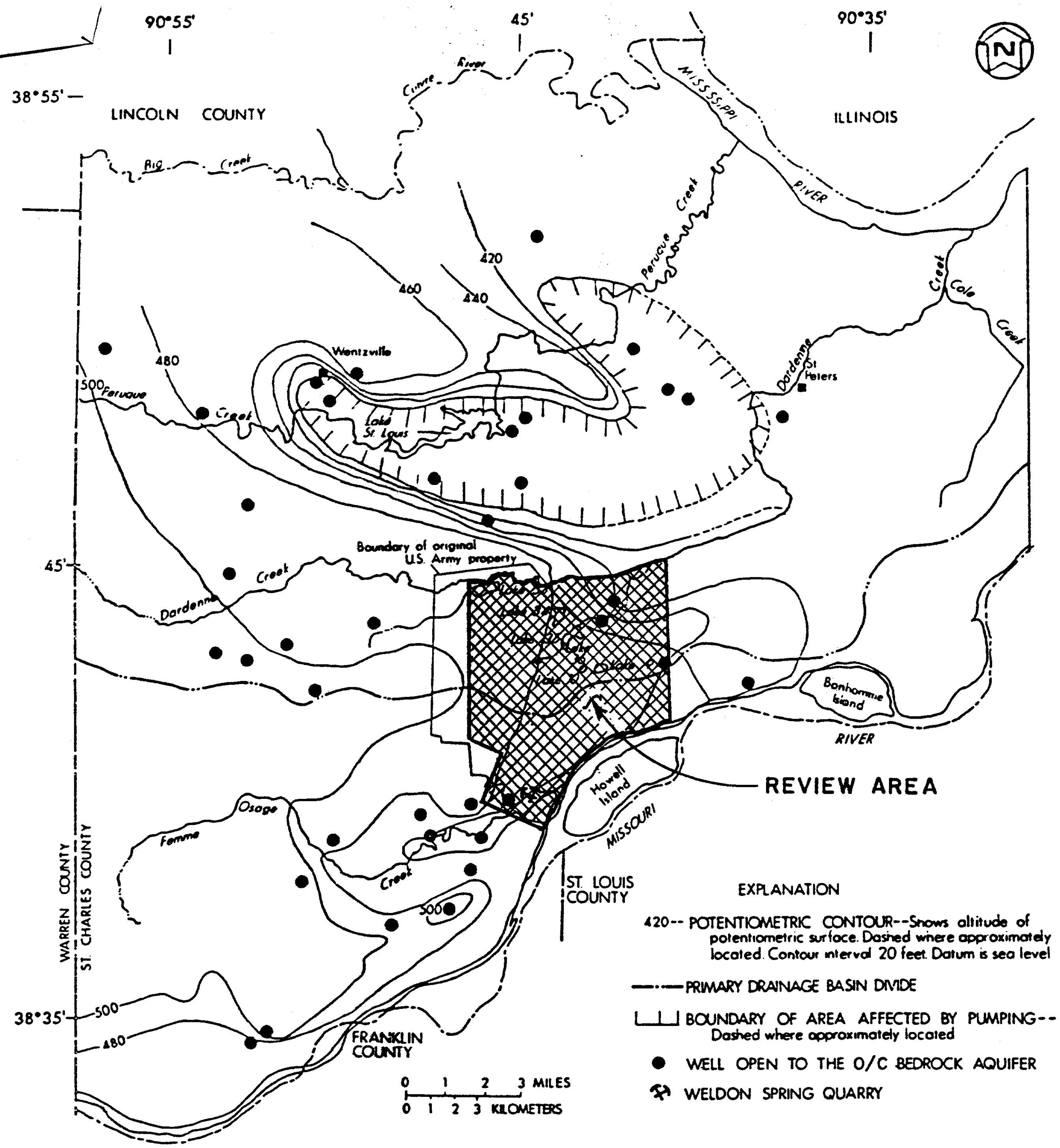


FIGURE 2-9

POTENTIOMETRIC SURFACE OF THE ORDOVICIAN/CAMBRIAN BEDROCK AQUIFER, SUMMER 1984

However, Bechtel indicates a depth of 18-20 feet at Raffinate Pit 4 (BNI, 1984).

2.4.2 Aquifer Properties

The upper 350 feet of the O/C section, the leaky confining layer, inhibits vertical migration of groundwater from the overlying M/D aquifer (Table 2.1). Near the Missouri River, the confining sequence of the O/C aquifer inhibits groundwater migration from the alluvium to the deeper water-bearing units of the O/C aquifer.

Porosity of the surface and near surface bedrock in the area is of primary and secondary nature. Primary porosity is that portion of the bedrock void space that is present within the matrix of the rock itself. Secondary porosity consists of solution channels, and/or fine interconnected fractures and vugs in the limestone bedrock (MKF, 1987b). The Burlington-Keokuk Limestone, the Fern Glen Limestone, and the Kimmswick Limestone are locally weathered where they crop out and may transmit water primarily through solution openings and joints (Kleeschulte and Emmett, 1986a).

Hydraulic or aquifer parameters of importance to the groundwater classification are: hydraulic conductivity, specific capacity, transmissivity, storativity, porosity, and dispersivity. Aquifer tests made on wells completed in the Kimmswick Formation to the St. Peter Sandstone in St. Charles County gave specific capacities of 0.07 to 0.25 gpm/ft of drawdown (Kleeschulte and Emmett, 1986a). Wells penetrating deeper formations had specific capacities ranging from 0.53 to 2.64 gpm/ft of drawdown (Kleeschulte and Emmett, 1986a).

To determine hydraulic properties of the Burlington-Keokuk Limestone at the WSCP/WSRP, several aquifer tests have been performed. The properties determined are hydraulic conductivity, transmissivity, storativity, effective porosity and dispersivity. Hydraulic conductivity was determined using data from slug tests and pumping tests. Transmissivity and storativity were calculated using data from pumping tests only. Effective porosity and dispersivity were found using data from tracer tests (MKF and JEG, 1989a).

Slug Tests

Slug tests in the Burlington-Keokuk Limestone have been performed on 72 individual monitoring wells in the WSCP/WSRP/ WSVP area. Values of hydraulic conductivity obtained from these tests vary across the area, ranging from 9.5×10^{-8} cm/s to 2.29×10^{-2} cm/s (MKF and JEG, 1989a).

Pumping Tests

Three separate pumping tests of the Burlington-Keokuk Limestone were performed in the WSCP/WSRP/WSVP area. Three networks consisting of one pumping and several observation wells were installed specifically for the performance of the tests. The data from these tests were analyzed to obtain values for the transmissivity and storativity of the formation. Transmissivities were found to range from 14.4 gpd/ft to 72.4 gpd/ft. The storativities ranged from 1.3E-4 to 8.1E-4 (MKF and JEG, 1989a).

Tracer Tests

Four converging flow tracer tests were performed in the WSCP/WSRP area at two of the three pumping test networks. The data from these tests were used to determine the effective porosity and dispersivity of the formation. Calculated effective porosities ranged from 0.002 to 0.02 and dispersivities were in the range of 0.002 to 0.004 ft (MKF and JEG, 1989a).

2.5 GROUNDWATER MOVEMENT

2.5.1 Weldon Spring Chemical Plant/Raffinate Pits/ Vicinity Properties

At the WSCP/WSRP/WSVP groundwater flow in the saturated portion of the Burlington-Keokuk Limestone occurs both as diffuse flow and discrete flow. Diffuse flow is that component of groundwater flow that is contained in intergranular pores or within closely spaced fractures and bedding planes, and can be assessed using Darcian principles. Evaluation of flow characteristics within the saturated portions of the Burlington-Keokuk has relied upon an equivalent porous medium approach. This approach has included the use of traditional hydrogeological investigation methods such as slug tests and pumping tests. The application of these methods at the WSCP has indicated that groundwater flow beneath the WSCP/WSRP/WSVP can be assessed to a limited extent using Darcian principles. These principles apply because the groundwater flows through the fine fractures of the formation, which comprise an equivalent porous medium.

Discrete (or conduit) flow is flow at much higher velocities than diffuse flow, within discrete (conduit) fractures or solution-enlarged openings. Conduit flow has not been detected on the WSCP/WSRP/WSVP but can occur where subsurface groundwater pathways are developed selectively within a fracture network. Conduits typically discharge into springs, seeps or other surface water bodies such as streams, rivers, and lakes. Dye trace tests have indicated that conduit flow does occur outside the boundaries of the WSCP/WSRP/WSVP within the highly weathered bedrock. Conduit flow in the Burlington-Keokuk is flashy, occurring during wet conditions as losing streams recharge subcutaneous drainage. Springs near the WSCP/WSRP/WSVP exhibit turbid increases in discharge during precipitation events. This is indicative of conduit flow discharge.

Some springs also exhibit perennial base flow which is indicative of diffuse flow discharge. Indeed, beneath the WSCP/WSRP/WSVP diffuse flow is predominant, because unconsolidated Pleistocene materials and fill prevent direct recharge of subcutaneous drainage which would yield discrete flow. Darcian flow is dispersive, while flow in conduit systems is convergent (Quinlan and Ewers, 1985).

In a continuous porous medium, which is isotropic with respect to hydraulic conductivity, the groundwater flow direction is perpendicular to the potentiometric surface elevation contours. In conduit flow, the flow direction can be oblique to contours. The general flow directions for the discussion below is based on flow in a continuous isotropic medium.

Groundwater flow directions in the upper M/D aquifer are influenced by the position and orientation of the groundwater divide at the WSCP/WSRP/WSVP. Flow is to the north from the northern part of the site and to the southeast or east in the southern portion of the site (Figure 2-7). In other words, north of the groundwater divide flow is to the north; south of the groundwater divide flow is to the south-southeast.

Flow directions in the O/C bedrock aquifer system can be inferred from the map in Figure 2-9. Groundwater movement as mapped by the USGS in 1984 is to the northeast and southeast.

In 1984, the head differential between the O/C and M/D groundwater aquifers was approximately 125 feet at the WSS.

Groundwater tends to move downward with this head differential. However, the effective vertical hydraulic conductivity between the two aquifers is unknown, and therefore, the significance of the vertical movement is unknown.

2.5.2 Weldon Spring Quarry

The groundwater flow direction in the Kimmswick Limestone and Decorah Formation is from the south WSQ rim toward the Femme Osage Slough. Groundwater levels in the bedrock at the south rim consistently measure about 10 feet higher in elevation than in the alluvium near the slough. Suspected pathways for the groundwater flow are through the pore spaces and fractures in the Kimmswick and Decorah formations. A groundwater elevation relationship established at the bedrock-alluvium interface indicates limited hydraulic connection. Water elevations were analyzed as a part of the assessment of the effect of drought conditions on contaminant migration from the WSQ; these analyses support historical data which indicate the WSQ pond elevation is 26 feet higher than the groundwater elevation of the juxtaposed alluvial aquifer (MKF and JEG, 1988a). This difference in elevation indicates poor hydraulic communication between the WSQ sump and the alluvial aquifer due to the low permeability of the aquifer materials. This information also confirms the Berkeley Geosciences report (1984) which notes that the fractures tighten with depth and appear to transmit very little water to the alluvium. Groundwater level data indicate the presence of a southeast gradient across the Femme Osage Slough (MKF and JEG, 1988a) (Figure 2-10).

The groundwater level in the alluvial aquifer in the St. Charles County Well Field is mainly influenced by the Missouri River elevation and by pumping rates in the water production wells. Depth to water level fluctuates from approximately 6

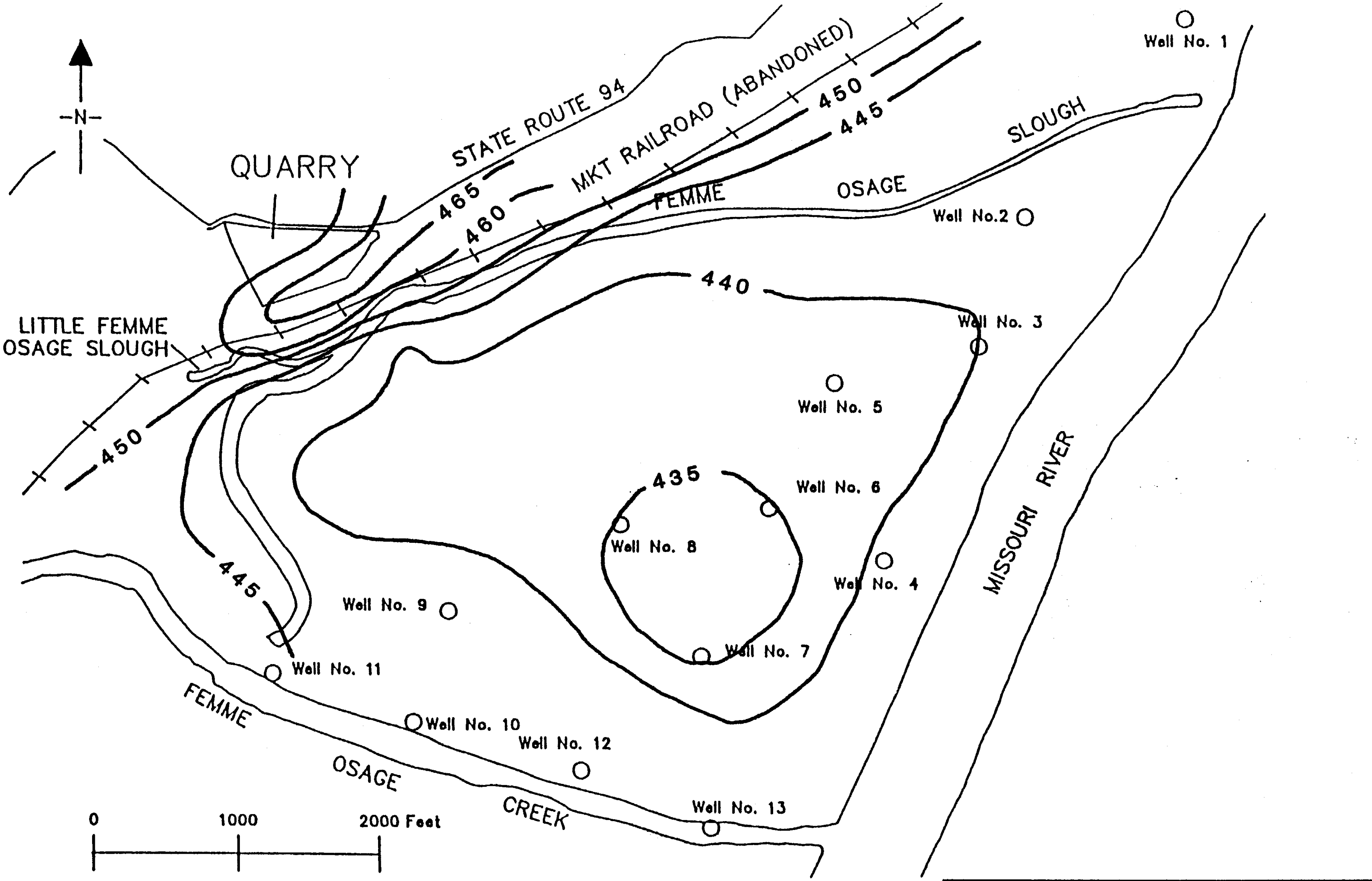


FIGURE 2-10
GROUNDWATER
ELEVATION
6-22-88
WELDON SPRING QUARRY
AND WELL FIELD AREAS

feet below ground surface (BGS) to approximately 20 feet BGS (Layne Western, 1986).

2.6 SPRINGS AND SEEPS IN THE WELDON SPRING SITE AREA

The objective of Phase I spring and seep sampling was to characterize the contaminants at the site and to identify the processes by which they migrate from the site. Sampling the spring waters was necessary to determine the extent of contaminant migration through groundwater via conduit flow. Spring and seep monitoring, in concert with a strategic monitoring well network, are a valuable source of information on the concentrations and migration of contaminants from the WSS.

Samples were taken from 27 springs and seeps. Many of these locations are wet-weather features which could be sampled only during very short times following periods of moderate to heavy precipitation.

The types of springs in the vicinity vary from small seeps at bedrock/clay contacts to solution-enlarged bedrock conduits and fractures that flow at rates of 200 gpm and more during precipitation events.

Many of the spring-type features, known as wet-weather springs, flow only after moderate to heavy rainfall. They generally flow for short periods and the flow is sometimes quite heavy, estimated to be 50 gpm.

2.6.1 Locations of Springs and Seeps

A field survey of springs was performed within a two-mile radius of the WSCP/WSRP/WSVP. Drainages were walked by geologists, and the location of each spring was mapped (Figure

2-11). A surface drainage numbering system was devised to aid in identifying and indexing the spring locations.

Other major springs outside the two-mile radius were indexed and sampled on the basis of their relationship with the WSS and on information from historical accounts of events at the Weldon Spring Ordnance Works (WSOW). The surface drainages were numbered so as to permit indexing of these more distant springs.

2.6.2 Water Quality in Springs and Seeps

The Phase I Spring and Seep Report (MKF and JEG, 1988b) did not indicate the presence of any contaminants attributed to the WSS in 16 of the 27 springs.

- Uranium was the only radioactive constituent found in any of the seeps and springs. It was found in seven locations; two in the 6300 drainage, four in the 5300 drainage, and one in the 5200 drainage (see Figure 2-11 for locations of drainages).

- No volatile organics were detected in any of the sampling locations.

- Nitroaromatic compounds were detected in at least one location each in the 5200, 5300, 5500, and 6300 drainages.

- Chloride and sulfate levels were found to be elevated above the background levels in only the 5200 drainage. These waters are probably contaminated from runoff originating from the Missouri Highway Department facility.

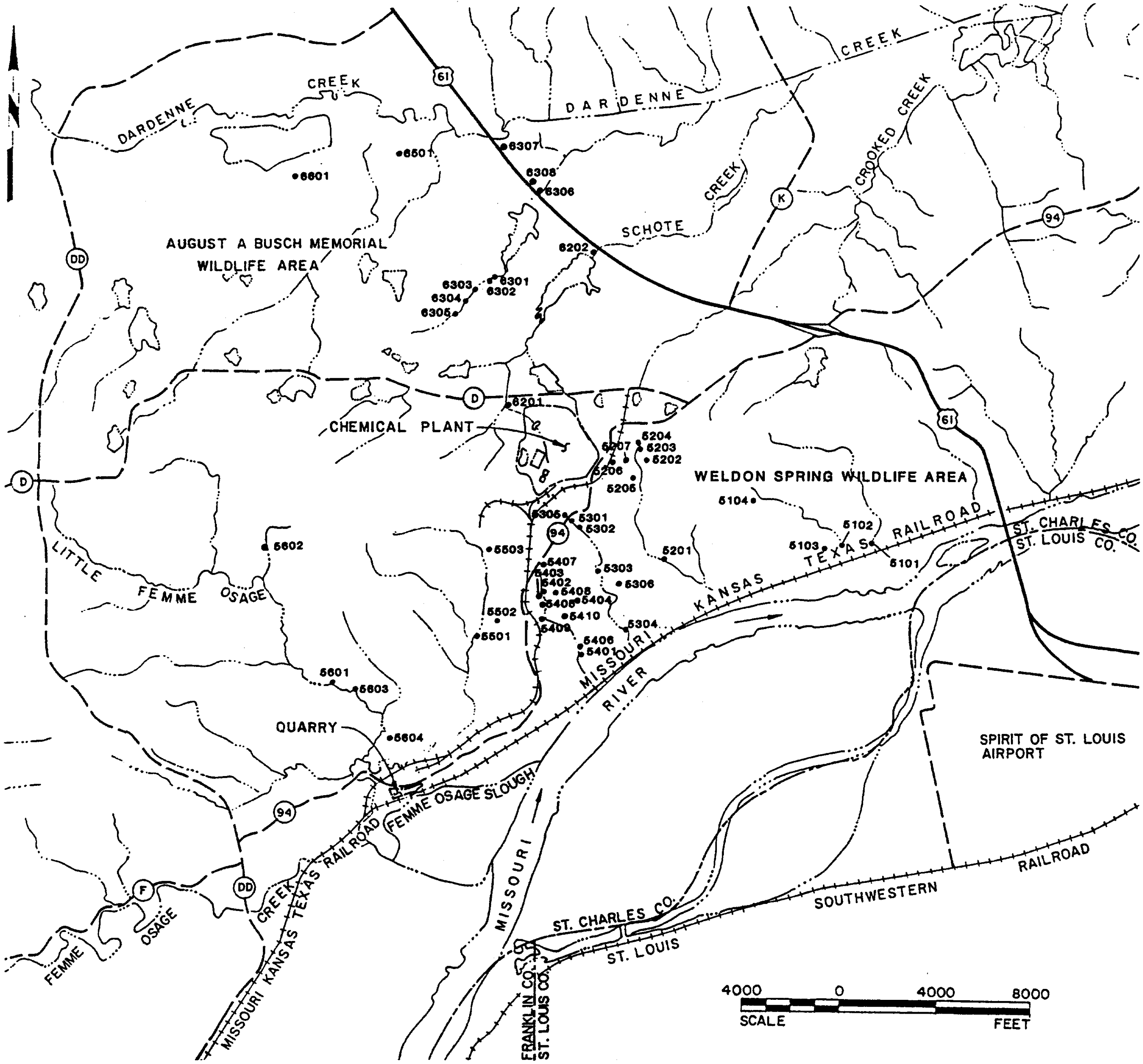


FIGURE 2-11

SPRINGS AND SEEPS IN THE VICINITY OF THE WELDON SPRING SITE

- Inorganic anion concentrations (other than chloride and sulfate) that were above background were located only in the 5200 drainage and at SP-6306. These concentrations are probably due to runoff originating from the adjacent Missouri Highway Department salt depot and from road surfaces treated with rock salt for snow and ice removal.

- Concentrations of four species of metals were found to be elevated above background levels. Elevated concentrations of sodium were detected in the 5200 drainage, also probably caused by runoff from the highway department chemical depot. Metals including aluminum, manganese, and lead were detected at elevated concentrations in several other springs around the area.

- No pesticides or polychlorinated biphenyls (PCBs) were detected at any locations.

2.7 GROUNDWATER QUALITY

2.7.1 Regional Groundwater Quality (Generalized)

The water quality of each aquifer system is discussed by Kleeschulte and Emmett (1986). Water from alluvial aquifers along the Missouri and Mississippi rivers is predominantly a calcium bicarbonate type, typically with high hardness levels and iron concentrations. The total dissolved solids (TDS) concentration is variable. The water quality of the M/D bedrock aquifer in St. Charles County varies from a calcium magnesium bicarbonate type to a sodium sulfate, bicarbonate, or chloride type. TDS and chloride concentrations increase from west to east. Naturally occurring sulfate concentrations are limited to areas underlain by Pennsylvania age shale, sandstone, and siltstone (Kleeschulte and Emmett, 1986b).

The water quality of the O/C bedrock aquifer varies laterally and vertically. Samples from the confining portion of the aquifer (the Maquoketa-Joachim sequence) have TDS values ranging from 305 to more than 4,700 mg/l. Water in the north and northeast portions of St. Charles County has high TDS and is a sodium chloride type, while water to the west is generally a calcium magnesium bicarbonate type. Water samples from the more permeable portion of the deep bedrock aquifer (the St. Peter-Gasconade sequence) had a TDS ranging from 252 to 915 mg/l. The eastern half of the county yields highly mineralized sodium chloride type water, whereas the western half yields moderately mineralized calcium magnesium bicarbonate type water (Kleeschulte and Emmett, 1986b).

2.7.2 <u>Weldon Spring Chemical Plant, Raffinate Pits, and Vicinity Properties Groundwater Quality</u>

The Phase II Groundwater Quality Assessment Report is the most current report (through the third quarter of 1988) on groundwater contamination at the WSCP/WSRP/WSVP (MKF and JEG, 1989). In 1988 the monitoring well network was extended by the addition of 33 new wells monitoring different for vertical and lateral characterization. The analytical categories for the study were inorganic anions, nitroaromatic compounds, radiochemical parameters, metals, and total organic carbon.

Nitrate contamination in groundwater is a result of leaking raffinate pits. The apparent sources of sulfate contamination are associated with the manufacturing of trinitrotoluene (TNT) and dinitrotoluene (DNT). Nitroaromatic compounds are present in the groundwater as a result of operations during World War II. Two monitoring wells indicate sporadic uranium levels greater than 40 pCi/l. Some metals concentrations in groundwater appear to be connected to the raffinate pits as a point source. Other metals are present in the groundwater, but point sources have not been identified for them (MKF and JEG, 1989a).

2.7.3 Weldon Spring Quarry Groundwater Quality

The Phase I Water Quality Assessment reported that groundwater contaminated with radiologic and nitroaromatic compounds is migrating from the WSQ, and the adjacent Femme Osage Slough is affected by that migration. The report recommends further investigation and characterization of groundwater quality at the WSQ (MKF, 1987c). This work is under way.

2.8 ECOLOGY

2.8.1 Habitat Types and Common Species

The following discussion of habitat types and common species in the classification review areas is summarized from the project Draft Environmental Impact Statement (DOE, 1987).

The WSS is located within the Bluestem Prairie, Oak-Hickory Forest Mosaic subsection of the Prairie Parkland province. The Oak-Hickory Forest subsection also occurs within the Weldon Spring area (Bailey, 1970; Galvin, 1979). Much of the area surrounding the site consists of state-owned wildlife areas containing secondary growth forest (August A. Busch Memorial Wildlife Area, Weldon Spring Wildlife Area, and Howell Island Wildlife Area). Nonforested areas occur over about 75% of St. Charles County.

Habitat types within the vicinity of the site include open fields and pastures, forests (upland, slope, and bottomland), and cultivated fields. These habitats have been characterized by the Missouri Botanical Garden (1975) and references therein. Cultivated fields contain harvestable crops whereas pastures contain herbaceous plants for grazing.

The areas surrounding the raffinate pits and chemical plant areas were formerly field habitat. However, mowing maintains much of these areas in a pasture-like condition. The abandoned chemical plant buildings, associated roads, parking lots and attendant utilities cover much of the WSCP/WSRP. Other ecological features of importance are Ash Pond, Frog Pond, and wooded areas.

Ash Pond is an ephemeral pond created by an earthen dam across a natural drainage. Since dumping activities were discontinued at this location, secondary vegetative growth has resulted in an ephemeral pond, old field, and secondary forest habitat.

Frog Pond is a 1/4-acre ecologic feature created by a small earthen dam across a natural drainage. It contains a resident population of sunfish and other aquatic vertebrates and invertebrates. It is also visited by waterfowl and large and small mammals.

A 5-acre area of secondary-growth forest is located on the north part of the WSCP site. It provides habitat for game animals such as deer, turkeys, rabbits, and squirrels and other small mammals.

The WSQ area consists of slope and bottomland forests with eastern cottonwood predominating in much of the area. Most of the habitat along the creeks and drainages in the vicinity properties is bottomland forest.

In the Busch Wildlife Area immediately north of the WSCP/WSRP, 277 species of birds have been observed. Of these, 103 species nest in the area and 43 are common to abundant throughout at least three seasons of the year (MDOC, 1981). About 10 waterfowl species are common to abundant during the spring and fall migration, and a few species such as Canada goose, mallard, and wood duck nest and/or winter in the area. The raffinate pits and quarry provide habitat suitable to water fowl. St. Charles County is within the range of over 50 reptile and amphibian species (Conant, 1975). Some of these species occur in the WSS area due to the variety of terrestrial and aquatic habitats.

Aquatic habitats in the vicinity of the site include intermittent and perennial streams, springs, ponds and lakes of various sizes, and the Mississippi and Missouri rivers that receive water from the St. Charles County drainage system. The lakes, ponds, and streams in the Weldon Spring vicinity sustains a warm-water fish community.

2.8.2 Rare and Endangered Species

It was concluded in the Environmental Impact Statement (EIS) that three endangered species may be present in the Weldon Spring vicinity: the bald eagle (Haliaeetus leucocephalus), the fat pocketbook mussel (Potamilus capax), and the Higgins' eye pearly mussel (Lampsilis higginsi) (EIS*). However, these two mussel species require a river habitat which is outside the classification review area (MDOC, 1984). The bald eagle, a mobile species, intermittently occupies the classification review area. The bald eagle once had a widely distributed breeding range across the North American continent. It declined as a nester in Missouri during early settlement because of human encroachment and habitat destruction. It was virtually eliminated by 1900. No nesting had been confirmed in Missouri since 1965 until a 1982 nest occurred in west central Missouri on Truman Reservoir. Significant numbers (800 to 1,200) winter in Missouri in waterfowl management areas, rivers, streams, and major impoundments (MDOC, 1984).

It is also stated in the EIS that additional rare and endangered species, both state and federally listed, may occur within the area. That statement is based on both habitat requirements and known distributions of those species. However, specialized habitat requirements and/or habitat preferences of these species are generally not met in the Weldon Spring area.

Four species that may occur within the Classification Review Area are classified as either rare or endangered by the Missouri Department of Conservation (MDOC, 1984). The Wood Frog (Rana Sylvatica) is classified as rare in Missouri. It has been observed in moist woodland habitats in east central Missouri. The Sicklefin Chub (Hybopsis meeki) and the Sturgeon Chub (Hybopsis gelida) are considered rare in Missouri. These two species can be found in the Missouri River and its larger tributaries. Hybopsis meeki is also a federal candidate species (Dieffenbach, 1988). The Cooper's Hawk (Accipites cooperii), is classified as endangered in Missouri. None of these species is currently listed as threatened or endangered by the federal government.

3 CLASSIFICATION REVIEW AREAS

Classifying groundwater on a site-specific basis requires a methodology for delineating a segment of groundwater to which the classification criteria may be applied. Classification Review Area (CRA) is the terminology used by the U.S. Environmental Protection Agency (EPA) for this concept (EPA, 1986). A CRA is normally defined by a two-mile radius from the boundary of the facility in question, but in some cases, unique hydrogeologic characteristics determine its real extent.

For example, one of these unique characteristics is karst topography. Karst topography is a type of topography that is formed as a result of limestone or dolomites dissolving or eroding, and is characterized by closed depressions, sinkholes, caves, subterranean conduit flow, and losing streams. The Weldon Spring Quarry (WSQ) is situated on limestones that locally exhibit features of karst topography. However, karst features are not present in the WSCP/WSRP area. Where karst features do exist, they are not extensive or pronounced enough to qualify as classic, mature karst topography. For the conservative purposes of this report, therefore, the CRAs in the Weldon Spring Site (WSS) are considered to be within an area of immature karst topography.

3.1 CLASSIFICATION REVIEW AREAS FOR THE WELDON SPRING SITE

Based on the hydrogeologic conditions described in Section 2 and following the EPA guidelines, the WSS has been subdivided into three CRAs as shown in Figure 3-1.

The WSCP/WSRP is located on the drainage divide between the Mississippi and Missouri rivers. The groundwater divide is a Type I CRA boundary for the site. Therefore two CRAs are designated at the WSCP/WSRP/WSVP. CRA I is located to the north

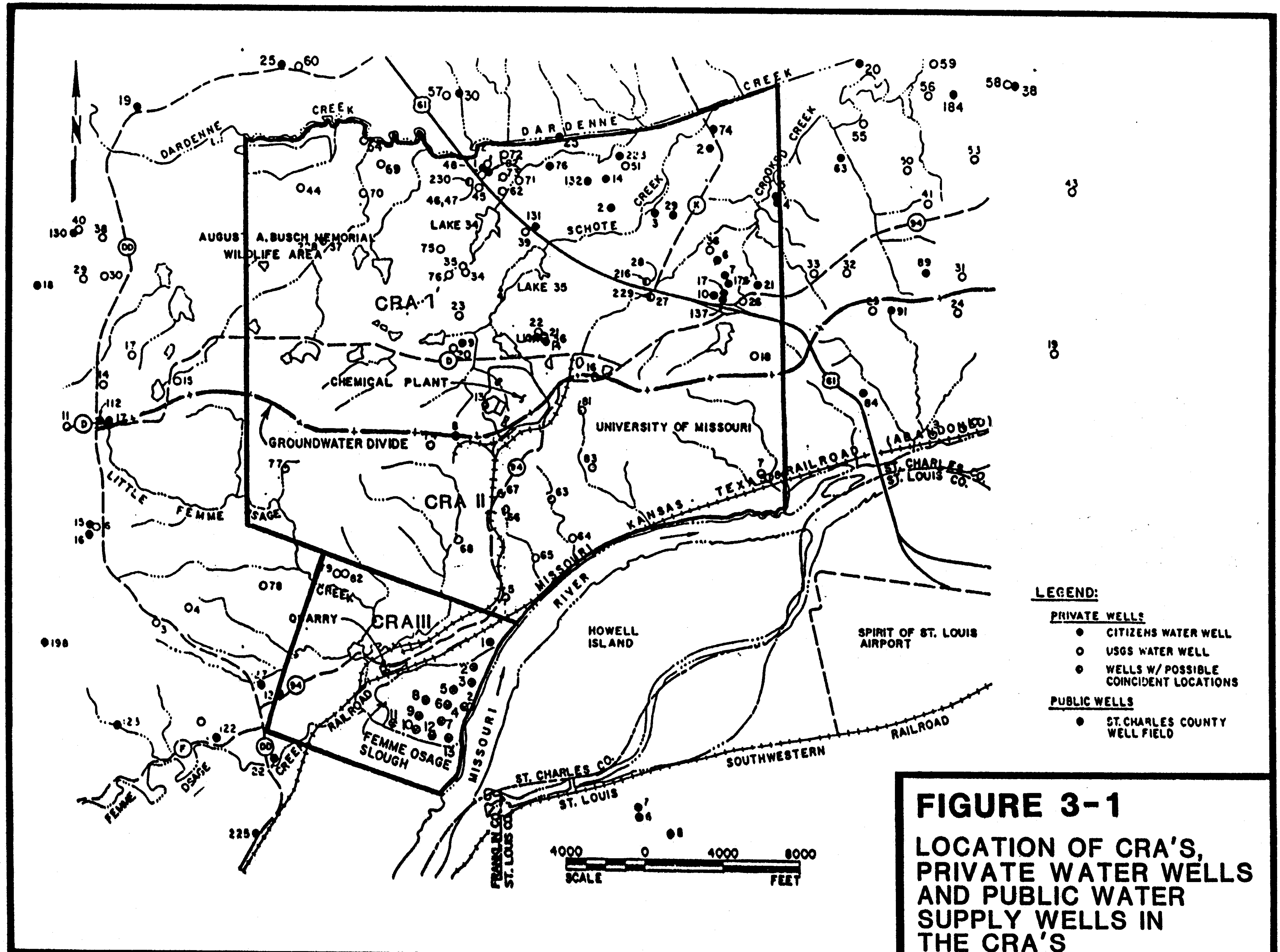


FIGURE 3-1

LOCATION OF CRA'S, PRIVATE WATER WELLS AND PUBLIC WATER SUPPLY WELLS IN THE CRA'S

of the regional groundwater divide and extends northward to the first perennial surface discharge at Dardenne Creek. Dardenne Creek is a gaining stream and is a significant discharge point for the O/C bedrock aquifer. CRA II extends from the groundwater divide south to the Missouri River. The linear distance to the eastern and western borders is equal to the distance from the WSCP/WSRP/WSVP to Dardenne Creek.

CRA III surrounds the WSQ. This area is an approximately square area drawn around the WSQ with the distance to each side equal to the distance between the WSQ and the Missouri River, which is the closest perennial discharge system.

3.2 CLASSIFICATION REVIEW AREA BOUNDARIES

The two WSCP/WSRP CRAs (CRA I and CRA II) and the WSQ CRA (CRA III) have been delineated by following the EPA Guidelines for defining these areas in karst terrain. The guidelines specify that a CRA boundary should extend to the nearest perennial surface water stream where the groundwater stream discharges.

The EPA also allows a CRA to be subdivided to reflect the presence of naturally occurring groundwater bodies that may have significantly different use and value. These groundwater bodies, referred to as "groundwater units," must be separated by units of low hydraulic conductivity such that an adverse change in water quality of one unit will not be likely to cause an adverse change in the water quality of an adjacent unit. Each groundwater unit is treated as a separate subdivision of the CRA. A classification decision is made only for groundwater units that may be affected by the activity or facility in question.

Groundwater units are delineated on the basis of three types of boundaries:

Type 1: Permanent groundwater flow divides.

Type 2: Extensive, low-permeability geologic units (confining beds), especially where characterized by favorable hydraulic head relationships across them. A favorable hydraulic head relationship means the groundwater flow is toward the portion of the aquifer most likely to be influenced by contamination from the facility of interest.

Type 3: Permanent fresh water/saline water contacts.

The EPA assumes that the type of boundary separating groundwater units reflects the degree of interconnection between them. Type 2 boundaries allow a low degree of interconnection. Type 1 and 3 boundaries imply an intermediate degree of interconnection. Types 1 and 3 are also prone to alteration and modification with changes in recharge.

4 WATER USE SURVEYS

4.1 PUBLIC WATER SUPPLY WELL SURVEYS

Water well surveys were conducted to determine if the groundwater serves as the sole-source water supply for a substantial population. The U.S. Environmental Protection Agency (EPA) guidelines for defining a substantial population allow either a quantitative or qualitative method. The EPA considers any population of 2,500 to be substantial and according to this definition, there is no substantial population of private well users in any of the three Classification Review Areas (CRAs). However, the public water supply well field in CRA III does serve a substantial population. In some cases, public and private water supply wells can be combined to make a substantial population of groundwater users.

Groundwater is the main source of public water supply in the St. Charles County area. The cities and public water supply districts served by a central water supply are listed in Table 4.1. Groundwater also supplies water for rural use and irrigation. Water for irrigation is withdrawn from wells in the Mississippi and Missouri river alluvium; the amount used varies with rainfall.

The principal groundwater extraction areas in the region of the Weldon Spring Site (WSS) are the St. Charles County well field (Figure 2-9), and the cities of Wentzville, O'Fallon, and St. Peters. Sources of municipal water for the area surrounding the WSS are given in Table 4.2. The larger communities of St. Charles, O'Fallon, and St. Peters rely on their own water sources. Public Water Supply District #2, Missouri Cities Water Company, Francis Howell High School, the Army, and a portion of the County all rely on the county well field for all or part of their water supply. Missouri Cities Water Company is a private

TABLE 4.1 Public Water Supply Facilities in St. Charles County

Municipality or Operating Agency	Source of Supply	Average Daily Consumption (10^6 gpd)
Portage Des Sioux	1 alluvial well	0.022
St. Peters	5 deep wells	1.500
O'Fallon	4 wells	0.972
Wentzville	4 deep wells	0.825
St. Charles PWSD No. 1	1 deep well	0.045
St. Charles County Water Division:		
Elm Point Plant	4 shallow wells	4.000
Missouri River Plant	Missouri River	0.400
Weldon Spring[a]	8 alluvial wells	2.728
St. Charles PWSD No. 2, East	4 alluvial wells	0.051
St. Charles PWSD No. 2, North	4 deep wells	0.677
St. Charles PWSD No. 2, West	1 deep well	0.014

[a] Referred to as the St. Charles County well field in this document.

Source: Missouri Department of Natural Resources (1982) as cited in DOE, 1987.

TABLE 4.2 Water Sources in St. Charles County

User	Community Water System	Water District #2	Missouri Cities Water Co.	St. Charles County
	Suppliers Relying on County Well Field			
St. Charles	X	–	X[a]	–
O'Fallon	X	–	X[a]	–
St. Peters	X	–	X[a]	–
Lake St. Louis	X	c	–	–
Weldon Spring Heights	X	–	–	–
Defiance	–	X	–	
Wentzville	–	X[b]	–	
Dardenne	–	X[b]	–	–
New Melle	–	X	–	–
Cottleville	–	–	X	–
Harvester Area	–	–	X	
Weldon Spring	–	–	–	X
Francis Howell High School	–	–	–	X
Army	–	–	–	X
All Saints Village[d]	–	–	–	–

X Major source of water

a Certain subdivisions within city limits served by Missouri Cities Water Company.

b Currently Public Water District #2 supplies water to the General Motors plant and will eventually supply water to the city.

c Water originates from well in Lake St. Louis but is administered by Public Water District #2.

d Water supplied by private wells.

Source: DOE, 1987.

company serving portions of St. Charles County, including certain subdivisions of the cities of St. Charles, O'Fallon, and St. Peters. The St. Charles County and St. Peters wells extract groundwater from the alluvial aquifer while the cities of Wentzville and O'Fallon extract from the O/C bedrock aquifer. The St. Charles County well field produces an average 10.5 million gallons per day (mgd) (MKF and JEG, 1988a). Monthly production data for the years 1984-1987 are summarized in Table 4.3.

4.2 PRIVATE WATER SUPPLY WELL SURVEY

4.2.1 U.S. Geological Survey Private Well Survey

The U.S. Geological Survey (USGS) has surveyed some of the private wells in St. Charles County. Static water level readings from these wells are used to supplement water level data from groundwater monitoring and observation wells to develop potentiometric surface maps for the area (Kleeschulte, 1988). The private water wells in the vicinity of the WSS are shown in Figure 3-1.

The USGS data base contains information on 25 private water wells located within CRA I. Twelve of these wells (numbers 8, 13, 26, 34, 44, 62, 70-73, 75, and 76) have never been located or surveyed by the USGS and it has no information on them other than the coordinates of their locations. The remaining 13 wells have been surveyed, and water level data from these wells were incorporated into the USGS regional well survey. Location coordinates, casing and water elevations, lithologies, and the names of the owners are listed in the USGS data base.

Fifteen private water wells included in the USGS data base are located in CRA II. Only the location coordinates are known for 12 of them (numbers 35, 63-68, 74, 77, 80, 81, and 83).

TABLE 4.3 Well Yields and Monthly Productions For the St. Charles County Well Field

Production Well	Production Capacity: Gallons/Minute (gpm)	Production Capacity: Million Gallons/Day (mgd)
PW-2	1639	2.36
PW-3	1757	2.53
PW-4	1993	2.87
PW-5	2125	3.06
PW-6	2146	3.09
PW-7	2132	3.06
PW-8	2083	3.00
PW-9	2139	3.08

MONTHLY WATER PRODUCTION
(million gallons)
ST. CHARLES COUNTY WELL FIELD

	YEAR				
Month	1984	1985	1986	1987	Average
JAN	132.547	134.567	166.311	162.059	148.871
FEB	125.419	132.183	156.433	203.179	154.304
MAR	141.618	155.310	175.344	200.000	168.068
APR	137.047	158.529	211.780	227.756	183.778
MAY	175.580	197.562	224.647	326.758	231.137
JUN	266.436	170.723	248.926	312.329	249.604
JUL	272.598	263.991	306.931	301.461	286.245
AUG	259.390	185.914	264.170	309.326	254.700
SEP	161.318	204.866	235.585	283.327	221.274
OCT	143.267	191.831	188.967	244.597	192.166
NOV	134.944	170.860	195.976	184.177	171.489
DEC	135.969	150.154	172.130	183.613	160.467
Total	2086.133	2116.490	2547.200	2938.582	2442.101

Source: Soil Consultants, Inc., 1988.

Water level data from the remaining three wells were used in the USGS summary of water level measurements in the M/D bedrock aquifer.

Two private water wells located in CRA III are listed in the USGS data base but reportedly have not been located or surveyed by the USGS. The USGS has no information on them other than their coordinates. A third well (#2 in the USGS data base) is part of the St. Charles County well field and is listed as belonging to the Atomic Energy Commission. This well is not a private well, even though it was included in the USGS survey.

4.2.2 St. Charles Countians Against Hazardous Waste Survey

St. Charles Countians Against Hazardous Waste (SCCAHW) surveyed private water wells in the vicinity of the WSS. Sources used to acquire information for this survey were the St. Charles County Administrative Court, Missouri Division of Health, Missouri Department of Natural Resources, Missouri Department of Conservation, and private research by the SCCAHW. Twenty-one water wells from this survey were located in CRA I. Four of them (216, 228, 229, and 230) are the same as wells listed by the USGS survey. No wells were identified by SCCAHW in CRA II. One well identified by SCCAHW is located in CRA III. Figure 3-1 shows the locations of water wells surveyed by the USGS and the SCCAHW.

4.3 DEMOGRAPHICS

The CRAs are located on the perimeter of the St. Louis metropolitan area in St. Charles County. Population trends of the greater St. Louis Standard Metropolitan Statistical Area (SMSA) are presented in Table 4.4. From 1960 to 1980, St. Charles County experienced the greatest percentage increase in

TABLE 4.4 Population of the St. Louis Standard Metropolitan Statistical Area

County/City	1960	1970	% Change 1960-70	1980	% Change 1970-80
Missouri					
St. Louis (City)	750,026	622,236	-17.0	453,085	-27.2
St. Louis County (less St. Louis City)	703,532	951,353	+35.2	973,896	+2.4
Franklin County	44,566	55,116	+23.7	71,233	+29.2
Jefferson County	66,377	105,248	+58.6	146,183	+38.9
St. Charles County	52,970	92,954	+75.5	144,107	+55.0
Illinois					
Madison County	224,689	250,934	+11.7	247,691	-1.3
St. Clair County	262,509	285,176	+8.6	267,531	-6.2
Clinton County[a]	---	---	---	32,617	---
Monroe County[a]	---	---	---	20,117	---
St. Louis SMSA	2,104,669	2,410,884	+14.6	2,356,460	-2.3

[a] Not included in the St. Louis Standard Metropolitan Statistical Area in 1960 and 1970.

Source: U.S. Bureau of the Census (1970, 1980a) (as cited in DOE, 1987).

population relative to the other counties within the metropolitan St. Louis area.

Population trends for communities in the region surrounding the WSS are indicated in Table 4.5. In 1980, the city of St. Charles had the largest population in the area, and O'Fallon and St. Peters had the next largest populations. Population projections for St. Charles County indicate a growth rate of about 70% from 1980 to the year 2000. According to projections by the East-West Gateway Coordinating Council (1983), the 1980 population of St. Charles County (approximately 144,000) is expected to grow to 190,000 in 1990, 217,000 in 1995, and 245,000 in 2000 under the high growth scenario.

Francis Howell High School is located approximately 1 km (0.6 mi) from the WSS on State Route 94. Enrollments are steadily increasing and current enrollment is approximately 2,000 students (DOE, 1987).

TABLE 4.5 Population of the Region Surrounding The Weldon Spring Site, 1960-1980

County/City	1960	1970	% Change 1960-70	1980	% Change 1970-80
Missouri					
All Saints Village	NA[a]	NA	NA	NA	NA
Defiance	NA	NA	NA	NA	NA
Harvester	NA	NA	NA	NA	NA
Cottleville	NA	230	NA	184	-20.0
New Melle	NA	NA	NA	168	NA
O'Fallon	3,770	7,018	+86.2	8,677	+23.6
St. Charles	21,189	31,834	+50.2	37,379	-17.3
St. Peters	404	486	+20.3	15,700	+3,130.0
Weldon Spring	NA	NA	NA	70[b]	NA
Weldon Spring Heights	NA	135[c]	NA	144	+6.7[c]
Wentzville	2,742	3,223	+17.5	3,193	-1.0

a NA indicates data not available.
b Bechtel National (Undated).
c National Lead Company of Ohio (1977).

Source: U.S. Bureau of the Census (1970, 1980a, 1980b), except as noted (as cited in DOE, 1987).

5 GROUNDWATER CLASSIFICATION

5.1 U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA) GROUNDWATER CLASSIFICATION SYSTEM

The EPA Groundwater Classification System recognizes three general classes of groundwater representing separate resource values. These classes are:

- Class I - Special groundwater (the highest use category). Class I groundwaters are considered to be resources of unusually high value. They are highly vulnerable to contamination and are irreplaceable and/or ecologically vital. The EPA has not settled on a methodology for defining "highly vulnerable." The EPA is also still in the process of defining "irreplaceable".

- Class II - Groundwater currently or potentially a source for drinking water and water having other uses. All non-Class I groundwater currently used (Class IIA) or potentially available (Class IIB) for drinking water and other beneficial use is in this category. A current source of drinking water is an area that contains operating drinking water wells or a water-supply reservoir watershed designated for water quality protection. A potential source of drinking water is one which is capable of yielding a quantity of drinking water (150 gallons/day) to a well or spring sufficient for the needs of an average family. EPA defines drinking water to be water with a total dissolved solids (TDS) concentration of less than 10,000 mg/l which can be supplied without treatment or which can be treated to this level by using methods reasonably employed in a public water supply system.

- Class III - Groundwater not a potential source of drinking water and of limited beneficial use. This category includes groundwater with total dissolved solids (TDS) levels over 10,000 mg/l. EPA also includes in Class III water that is so contaminated by naturally occurring conditions or the effects of broad-based human activity (i.e., unrelated to a specific activity), that it cannot be cleaned up using treatment methods reasonably employed in public water supply systems.

This classification system is based on drinking water as the highest beneficial use of the resource. The system was designed to be used in conjunction with the site-by-site assessments typically conducted by the EPA when issuing permits and deciding on appropriate remedial action.

The EPA procedures for groundwater classification include a classification chart of the decision-making process (Figure 5-1).

5.2 DATA NEEDS

Preliminary data needed for the classification determination include:

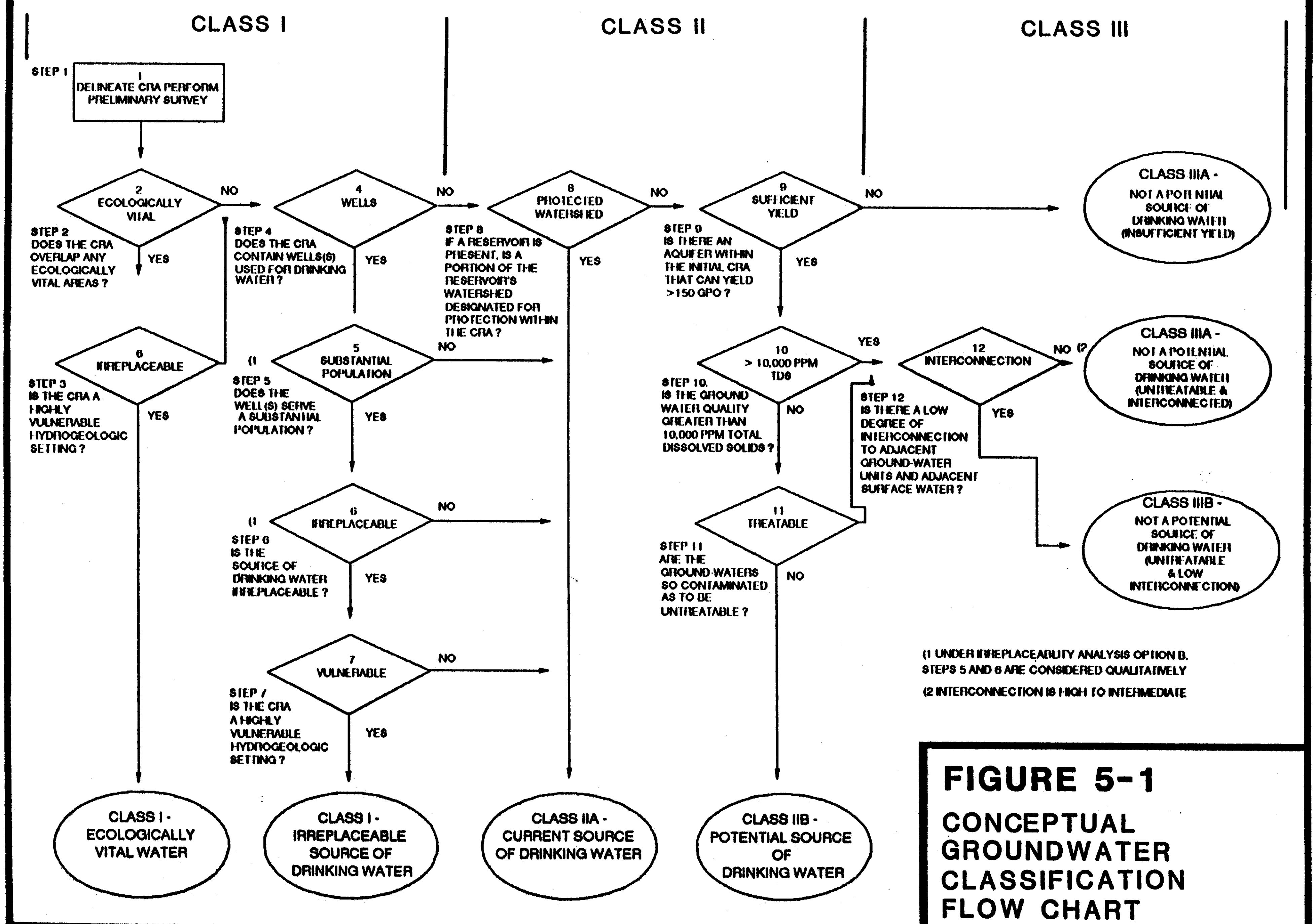


FIGURE 5-1
CONCEPTUAL GROUNDWATER CLASSIFICATION FLOW CHART

- Base map of the Classification Review Area (CRA).
- Inventory of public water-supply systems in the CRA.
- Delineation of areas served by private water wells.
- Demographic information on the public water supply systems and areas of private water wells.
- Hydrogeological data sufficient to judge vulnerability or support interconnection analysis.
- Survey of ecologically vital areas.

Material presented in Sections 2 through 4 addresses the required preliminary data needs. Several different hydrogeologic and environmental studies have been done at the WSS for the remedial investigation and feasibility study (RI/FS) process. This information, which is summarized in Section 2, is adequate to classify groundwater at the three CRAs associated with the Weldon Spring Site (WSS).

5.3 CLASSIFICATION PROCEDURE

The following sections follow the flow chart, evaluating the groundwater of the CRAs step by step.

5.3.1 Ecologically Vital Areas

The first criterion for evaluating Class I groundwater is to determine if it is ecologically vital. The EPA classifies groundwater as "ecologically vital" if it supplies a sensitive ecological system located in a groundwater discharge area that supports a unique habitat. A sensitive ecological system is interpreted as an aquatic or terrestrial ecosystem located in a groundwater discharge area.

A groundwater discharge area is an area of land beneath which there is a net annual transfer of water from the saturated zone to a surface water body, the land surface, or the root zone. The groundwater discharge is physically manifested by an increase of hydraulic head with depth (i.e., upward groundwater flow). Features such as seeps, springs, wetlands, and streams are associated with natural areas of discharge. All three CRAs contain areas of groundwater discharge within their boundaries.

A unique habitat is primarily defined as a habitat for a listed or proposed endangered or threatened species, as designated pursuant to the Endangered Species Act.

As stated in Section 2.8.2, no federally endangered or threatened species are known to inhabit the CRAs. Four species rare to Missouri, but not on the federal list, have been identified. However, habitats to support these species are not presently known to be affected by groundwater discharge.

Federal land management areas may also be considered unique habitats for groundwater protection. Among those most likely to be included are portions of national parks, national wilderness areas, national wildlife refuges, and national research natural areas. No federal land management areas exist in the CRAs.

On the basis of this evaluation, groundwater discharging in the three Weldon Spring CRAs does not supply ecologically vital areas.

5.3.2 Irreplaceability

Groundwater within each CRA must be evaluated for its irreplaceability. The goal of this evaluation is to identify groundwater of such relatively high value that unusually high protection is warranted. A groundwater supply serving a substantial population is considered irreplaceable if alternative sources are not suitable due to any one or more of the following five criteria:

- o Use of the alternative source would require piping water over an unreasonable or uncommon distance.
- o The alternative source is incapable of providing water of quality that is comparable to typical quality of groundwater used for drinking in the region.
- o The alternative source is incapable of yielding water in sufficient quantity to serve the substantial population.
- o Access to the alternative source is precluded by institutional constraints.
- o Use of the alternative source is economically not feasible.

The initial step to determine irreplaceability is to decide if the CRAs contains wells used for drinking water. Both CRA I and CRA II contain private use water wells. CRA III contains both private water wells and a public water supply well field (Figure 3-1).

The second step is to determine if the groundwater within a CRA serves a substantial population (at least 2,500 people). The St. Charles County well field located in CRA III currently serves approximately 50,000 to 55,000 people (Ahrens, 1988). No public water supply wells are located in CRA I or CRA II, therefore there is no need to evaluate those areas for irreplaceability (Figure 5-1).

In CRA III, a substantial population is served by the public water supply well field. Therefore, if an uncommon pipeline distance would be required to replace it, it would be a Class I resource. Uncommon pipeline distance is determined by establishing a hypothetical radial boundary around the site within which an alternative source of water should be located. If no alternative available water source of comparable quality and quantity can be located within this boundary, the groundwater in CRA III should be classified as a Class I resource.

EPA guidelines have established the minimum uncommon pipeline distance to be 25 miles for a minimum population of 5,000. Service to larger populations justifies greater minimum pipeline distances. However, the Missouri River and associated alluvial plains are clearly within the required distance and are surface and groundwater sources of comparable quality to the St. Charles County well field. Siting a well field in similar alluvial deposits up river from CRA III would offer water of comparable quality and quantity without substantially affecting the pipeline distance. Groundwater from the St. Charles County well field is primarily Missouri River water (Layne Western, 1986). Therefore, any other source of groundwater or surface water from the Missouri River is of comparable quality. The EPA defines "comparable quality" as a level of water quality that is not substantially poorer than other raw drinking water resources in the EPA region.

The third step to determine irreplaceability of a water supply is implemented if the previous criteria of substantial population, uncommon pipeline distance, and comparable quality are all met. In this step, institutional constraints upon usage of the alternate supply must be identified. The EPA defines institutional constraint as "a situation in which, as a result of legal or administrative restriction, delivery of replacement water may not be assured through simple administrative procedures or market transaction." There are no known constraints on water usage in the vicinity of the WSS. (Ahrens, 1988)

The final step for classifying groundwater is determination of the economic feasibility or infeasibility of replacing the existing water supply system. The EPA has defined the economic feasibility of an alternative water source principally in terms of the ability of a community to pay for it. The EPA offers two options for analyzing this. The first is a quantitative method of analysis comparing annualized replacement cost with per capita income. A rough estimate of the costs of the alternative water system would be used. However, such an analysis is beyond the scope of this report.

Under a second option, economic feasibility is determined by addressing cost and the community's ability to pay in a more qualitative fashion. This option seems adequate to apply to the area supplied by the St. Charles County well field for several reasons. The area has an ample water budget. Locating an alternate well field or surface water supply is highly probable. The St. Charles County well field is not the sole source of supply for most of the communities it supplies (see Table 4.2); therefore, additional capacity might be available by simply expanding existing alternate supplies. This scenario seems feasible and may significantly lower potential replacement costs. The size of the population disperses the replacement costs over a wider base than if the well field were the sole source for a single community.

Consideration of the above factors leads to the conclusion that it is economically feasible to replace the St. Charles County well field with an alternative supply of comparable quality and quantity. Replacement could be accomplished without economic hardship to the populations served by this source. Therefore, the groundwater in CRA III is not irreplaceable.

5.3.3 Vulnerability

Class I groundwaters are characterized, in part, by the fact that they are highly vulnerable to contamination (Figure 5-1). If groundwater is not considered ecologically vital or irreplaceable, a vulnerability analysis is not required. Groundwater in the three CRAs has been evaluated and found to be neither ecologically vital nor irreplaceable, and therefore by default, aquifer vulnerability is not an issue requiring study. However, the issue of vulnerability is of high priority to the U.S. Department of Energy (DOE).

EPA guidelines offer two ways of evaluating hydrogeological settings for vulnerability. The first relies on a numerical ranking scheme known as "DRASTIC;" the second utilizes a more qualitative, specific approach which reaches a conclusion through application of professional judgment. The DOE has commissioned both an applicable contaminant transport model and a "DRASTIC" evaluation for CRA II. A "DRASTIC" vulnerability evaluation is presented in Appendix B.

Argonne National Laboratory has issued a report (ANL, 1989) on contaminant transport near the Weldon Spring Quarry (CRA III) which examines the effect on contaminant transport of disturbing the source of contamination during remediation activities. This report evaluates the vulnerability of the aquifer in terms of its geology, the relevant contaminants, groundwater velocity, and distance to the well field.

5.4 GROUNDWATER CLASSIFICATION DECISION

The classification decision is the final determination of the relative value of the groundwater as a drinking water resource. The general procedure for this process is summarized by the flow chart in Figure 5-1. Figures 5-2, 5-3 and 5-4 contain specific flow charts for each of the three CRAs. A classification worksheet which briefly describes the rationale for each decision is provided in Appendix A.

Based on data input into decision trees provided by the EPA groundwater classification scheme, groundwater in all three CRAs is classified as Class IIA Current Source of Drinking Water. The EPA considers Class II groundwater to comprise the majority of the nation's groundwater resources with 80% to 90% of all groundwater falling within this category. Groundwater currently used for drinking water falls within Class IIA unless Class I criteria apply. All three CRAs at the WSS contain private drinking water wells in current use. Therefore, groundwater in all three CRAs cannot be considered Class III.

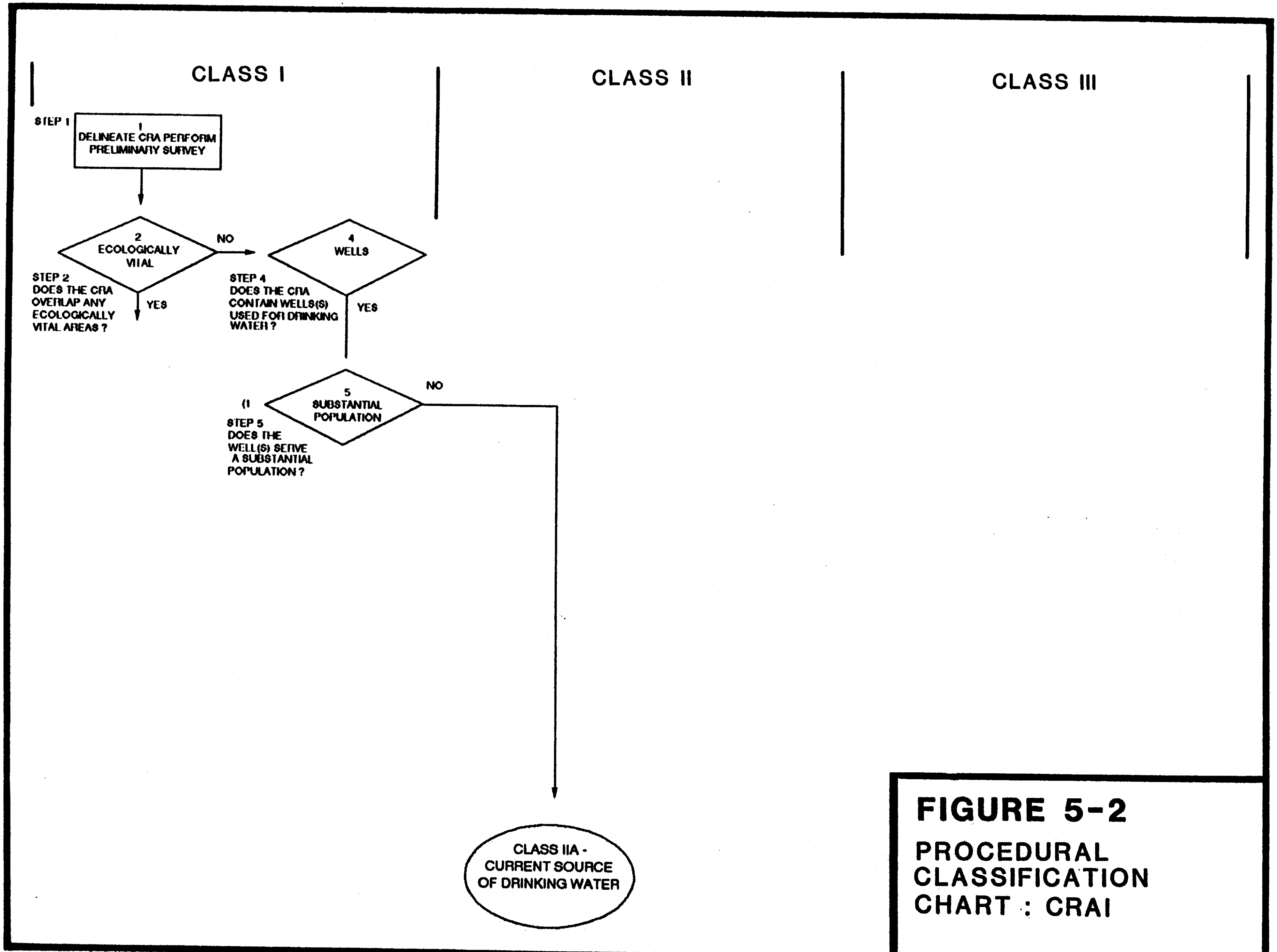


FIGURE 5-2

PROCEDURAL CLASSIFICATION CHART : CRAI

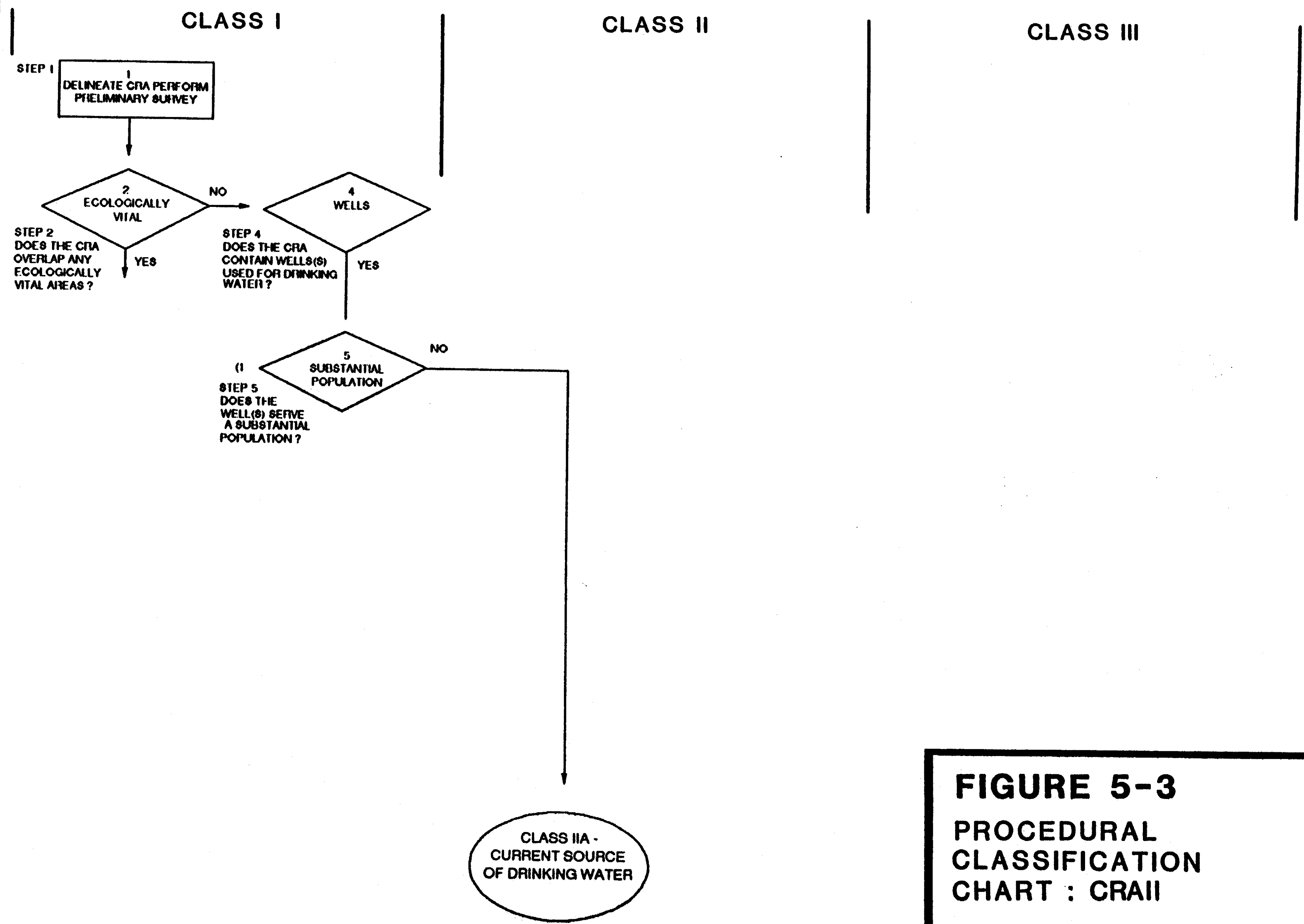


FIGURE 5-3

PROCEDURAL CLASSIFICATION CHART : CRAII

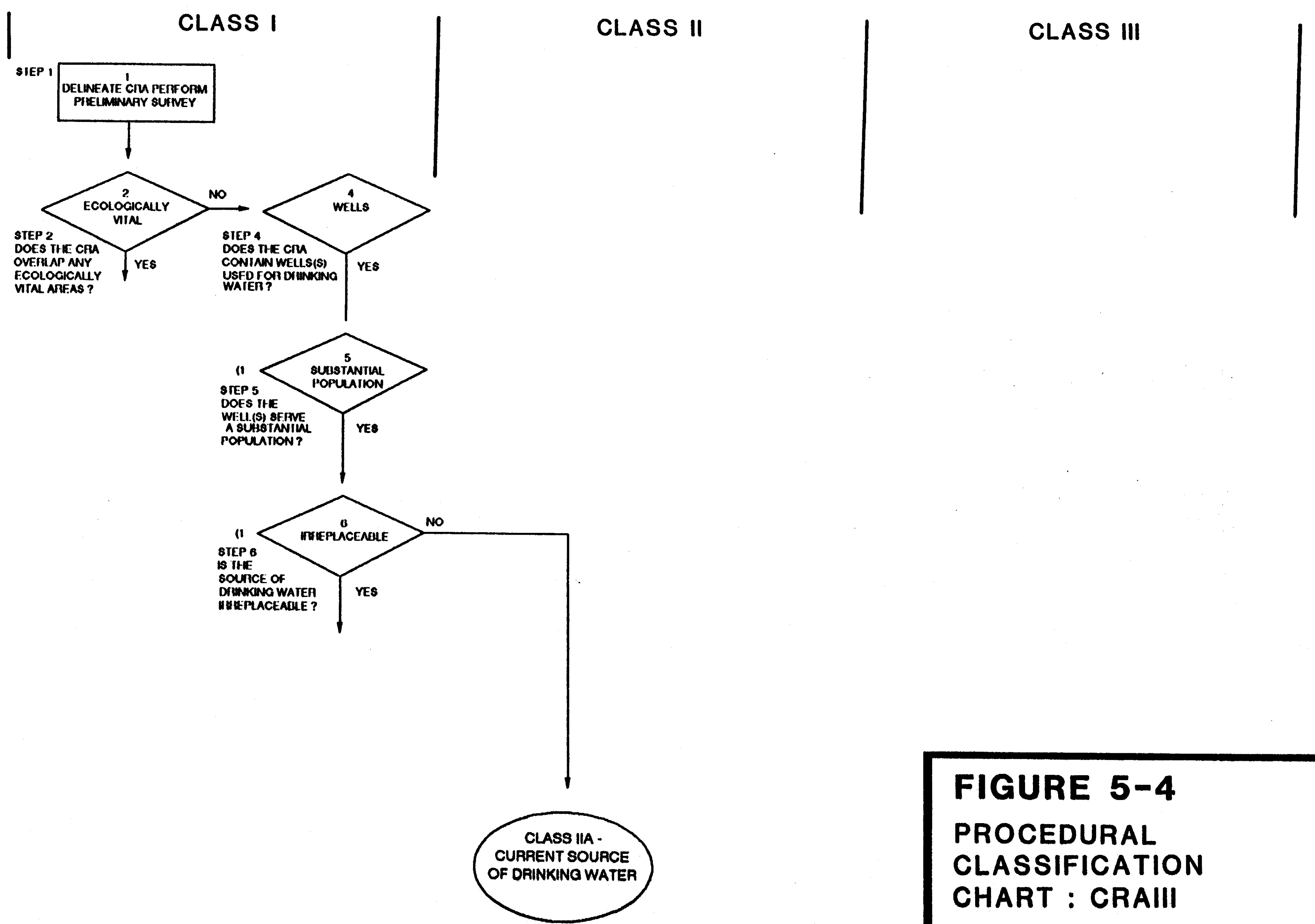


FIGURE 5-4
PROCEDURAL CLASSIFICATION CHART : CRAIII

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APPENDIX A
CLASSIFICATION WORKSHEETS

The following classification was performed based on the flow charts shown in Figure 5-1 of the main text and the associated worksheet from the EPA Guidelines for Groundwater Classification (EPA, 1986). Flow charts for each of the three CRAs are shown on Figures 5-2, 5-3, and 5-4.

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) collect preliminary information. Optional - demonstrate subdivision of the CRA.	Three CRAs were defined, two for the WSS and one for the Quarry. These three CRAs were delineated according to the EPA guidelines for karst terrain. This results in an area that may be larger than the standard two-mile radius normally used. Only the upper groundwater unit is being classified. The deep aquifer in the St. Peter Sandstone is considered to be sufficiently hydraulically disconnected from the upper alluvial and bedrock aquifers to prevent contamination from reaching this deep bedrock aquifer.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? o Yes, go to next step o No, go to step 4	There are no ecologically vital areas present within any of the three CRAs.
4	Determine the location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? o Yes, go to next step o No, go to step 8	The CRAs all contain private wells that are used to supply drinking water. CRA III also contains public water supply wells that serve 50,000 - 55,000 people.

5	Inventory population served by well(s). Does the well(s) serve a substantial population? o Yes, go to next step o No, than the groundwater is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	CRA I does not serve a substantial population of private well users. There are no public water supply water wells located in CRA I. CRA II also does not serve a substantial population of private well users. There are not public water supply wells located in CRA II. CRA III also does not serve a substantial population of private well users. A public water supply well field within CRA III does serve a substantial population. Classification decisions for CRA I and II can be made at this time. Since the water is not irreplaceable and does not serve an ecologically vital area, it can be classed as IIA CURRENT SOURCE OF DRINKING WATER.
6	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional-perform irreplaceability analysis. Is the source of drinking water irreplaceable? o Yes, go to next step o No, then the groundwater is CLASS IIA-CURRENT SOURCE OF DRINKING WATER.	An irreplaceability analysis has been performed on all three CRAs (see Section 5). No groundwater sources were considered irreplaceable. CRAs I and II have already been classified as II-A CURRENT SOURCE OF DRINKING WATER.

Final Class Determination:

CRA I - Class IIA, Current Source of Drinking Water
CRA II - Class IIA, Current Source of Drinking Water
CRA III - Class IIA, Current Source of Drinking Water

APPENDIX B
"DRASTIC" ANALYSIS

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APPENDIX B

DRASTIC employs a numerical ranking scheme to estimate vulnerability. In regions where estimated annual potential evapotranspiration exceeds mean annual precipitation, the DRASTIC criterion for highly vulnerable is 120. In regions where estimated annual potential evapotranspiration does not exceed mean annual precipitation (such as the case at the WSS and Quarry), the DRASTIC criterion for highly vulnerable is 150. DRASTIC is an acronym representing seven key hydrogeologic factors correlated to the potential for groundwater contamination listed below.

D-Depth to the water table.
R-Net Recharge to groundwater.
A-Aquifer media.
S-Soil media.
T-Topography (slope of the land).
I-Impact of the vadose zone.
C-Hydraulic Conductivity of the subject groundwater flow system.

A preliminary assessment of the three CRAs using the DRASTIC rating system has been completed and the results summarized in Table B.1. The total score for the M/D aquifer is 108, and the total score for the O/C aquifer is 113. The total score for the alluvial aquifer is 190. The numerical score indicates that if the water supply was ecologically vital or irreplaceable, the groundwater in the bedrock aquifers would not be considered vulnerable, but groundwater in the alluvial aquifer would be considered vulnerable.

Because the water supplies are tentatively determined to be neither ecologically vital nor irreplaceable, the question of vulnerability is a moot point and these results are presented as a matter of interest only. They should not be considered relevant to the mainstream classification process.

If the groundwater resources are given a DRASTIC vulnerability rating based on each CRA, the results would be as follows:

CRA I - Virtually all near-surface groundwater occurs in the M/D aquifer; hence this area is given a DRASTIC rating of 108.

CRA II - Virtually all near-surface groundwater occurs in the M/D aquifer, hence this area is given a DRASTIC rating of 108.

CRA III - Approximately 60% of the near-surface groundwater occurs in the O/C aquifer, and 40% of the groundwater occurs in the alluvium.

Unit	DRASTIC Rating	Area Percent	Score
O/C Aquifer	113	60	67.8
Alluvial Aquifer	190	40	76
			143.8

Therefore, CRA III receives a DRASTIC rating of 143.8.

TABLE B.1
DRASTIC METHODOLOGY TO ASSESS VULNERABILITY

Groundwater Unit DRASTIC Factor	Type or Range	Rating	Weight	Score
M/D AQUIFER*				
Depth to Water	30-65 ft	4	5	20
Net Recharge	10+ inches	9	4	36
Aquifer Media	Fractured Limestone	9	3	27
Soil Media	Silt/Clay loam	4	2	8
Topography	2-6% slope	9	1	9
Vadose Zone Media	Silt/Clay	1	5	5
Hydraulic Conductivity	100 gpd/ft^2	1	3	3
	TOTAL			108
O/C AQUIFER*				
Depth to Water	30-50 ft	5	5	25
Net Recharge	10+ inches	9	4	36
Aquifer Media	Fractured Limestone	9	3	27
Soil Media	Silt/Clay loam	4	2	8
Topography	2-6% slope	9	1	9
Vadose Zone Media	Silt/Clay	1	5	5
Hydraulic Conductivity	100 gpd/ft^2	1	3	3
	TOTAL			113
ALLUVIAL AQUIFER				
Depth to Water	5-20 ft	9	5	45
Net Recharge	10+ inches	9	4	36
Aquifer Media	Sands	9	3	27
Soil Media	Sandy loam	6	2	12
Topography	0-2% slope	10	1	10
Vadose Zone Media	Silt/Clay/Sand	6	5	30
Hydraulic Conductivity	4250 gpd/ft^2	10	3	30
	TOTAL			190

* Near-surface fractured zone

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